PICES SCIENTIFIC REPORT
No. 49, 2015

Report of the Study Group on Biodiversity Conservation

NORTH PACIFIC MARINE SCIENCE ORGANIZATION

ISBN 978-1-927797-19-8
ISSN 1198-273X

PICES

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This report was developed under the guidance of the PICES Science Board. The views expressed in this report are those of participating scientists under their responsibilities.

This document should be cited as follows:

Curtis, J.M.R. (Ed.) 2015. Report of the Study Group on Biodiversity Conservation. PICES Sci. Rep. No. 49, 61 pp.

PICES Scientific Report No. 49
2015

Report of the Study Group on Biodiversity Conservation

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PICES

August 2015
Secretariat / Publisher
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Executive Summary

Marine biodiversity is important for maintaining ecosystem structure and function which, in turn, supports sustainable fisheries. Understanding the drivers of biodiversity change (*e.g.*, non-indigenous marine species, climate change, eutrophication, fishing, pollution, *etc*.) and their interactions can help to inform policy makers and managers on decisions related to ecosystem-based management that balance multiple objectives. PICES has no formal mechanism to exchange information or to provide advice on issues related to biodiversity in the North Pacific despite recent requests to do so, for example, from the Convention on Biological Diversity (CBD). At the same time, other intergovernmental organizations have recognized the need to advance research focused on biodiversity. These include the Strategic Initiative on Biodiversity (SIBAS) within the International Council for the Exploration of the Seas (ICES) and the Medium-Term Strategy within the Northwest Pacific Action Plan (NOWPAP). In addition, the North Pacific Fisheries Commission (NPFC), which includes all PICES member countries, recently brought into force a new convention on marine conservation. This convention requires member countries to study, conserve and manage vulnerable components of marine biodiversity in international waters of the North Pacific Ocean. Thus, PICES, as a science organization, is well positioned to participate in facilitating the collaborative science needed to address biodiversity priorities in the North Pacific Ocean and to partner with other international organizations, such as ICES, NOWPAP, NPFC, CBD, and FAO.

At PICES-2013 the Study Group on *Biodiversity Conservation* (SG-BC) was approved, and formally established in January 2014. The following month, SG-BC members began proposing ideas related to the Group's terms of reference to lay the foundation for the structure and content of this report. A list of drivers of biodiversity change in the North Pacific Ocean identified by each PICES member country was reviewed by SG-BC. A list of key knowledge gaps that were regarded as priorities in each member country was compiled, as well as research questions relevant to PICES, which were grouped into five themes:

- Baseline inventories of biodiversity, including species and habitats;
- Analyses to understand and predict spatial patterns in species or habitat distributions;
- Monitoring to understand drivers of temporal trends in biodiversity;
- Vulnerability assessment of species and habitats;
- Analytical methods for marine spatial planning and ecosystem-based management.

Realizing that the breadth of identified knowledge gaps and research priorities would not be feasible to address with the timeframe of a single expert group, SG-BC devised a list of criteria by which to evaluate the merits of potential research avenues. Three ideas were proposed and evaluated against these criteria:

- Develop a plankton/nekton biodiversity network;
- Develop technical guidance on how to monitory biodiversity;
- Study the diversity and distribution of biogenic habitat.

The third option, researching the diversity and distribution of biogenic habitats, was favourably assessed against all evaluation criteria.

SG-BC's review of PICES past activities reveals that biodiversity science was recognized as a significant emerging issue by the Organization as early as 2000. Based on its assessment of research priorities, and past and present PICES activities, SG-BC recommends the establishment of a *Working Group on Biodiversity and Biogenic Habitats,* with an initial focus on coral- and sponge-dominated ecosystems. The proposed Working Group will advance understanding of the distribution of coral and sponge taxa in the North Pacific Ocean and their contribution to biogenic habitats and biodiversity. This effort represents a new emphasis on habitat research for PICES, and the initial focus on biogenic habitat could provide a proof of concept on how to undertake biodiversity research related to other taxa/ecosystems. Major applications of the science products developed by the Working Group would be provision of technical guidance on the development and application of species distribution models, maps of known and predicted distributions of biogenic habitats, and the development of biodiversity indicators.

1 Introduction

The conservation of marine biodiversity has long been recognized as important, not only in terms of its inherent worth, but also because of the broad range of ecosystem services provided by diverse marine ecosystems (Costanza *et al*., 1997), including the provision of food, stabilization of coastal areas, and sequestration of carbon. During the past two decades, world leaders have committed to implementing measures to conserve biodiversity and ensure its sustainable use in national waters and areas beyond national jurisdiction. Achieving both conservation and sustainable use of marine biodiversity in coastal and oceanic ecosystems could be achieved through processes of systematic conservation planning (Ban *et al*., 2014) based on knowledge of the distribution of biodiversity and factors – both environmental and anthropogenic – that influence its distribution.

The North Pacific Ocean is rich in biodiversity. For instance, to date 4,000 marine species belonging to 52 phyla and 105 classes have been recorded from Peter the Great Bay, Russia, alone (Institute of Marine Biology, FEB RAS). As researchers survey ecosystems deeper and farther offshore, new species are discovered and described (*e.g*., deep-sea barnacles, Chan *et al*., 2010; glass sponges, Reiswig, 2014). While species have been recorded to depths of 6,000 m (Vinogradov and Shushkina, 2002), biodiversity is generally richest at intermediate depths (Smith and Brown, 2002; Kitahashi *et al*., 2013). Species assemblages differ among regions (Zhu *et al*., 2011) and are often structured over large spatial scales (*e.g*., mesopelagic macrozooplankton, Stemmann *et al*., 2008) and in relation to the distribution of interacting trophic levels (*e.g*., Sydeman *et al*., 2010) or physiological constraints imposed by environmental conditions (*e.g*., sharks, Priede *et al*., 2006). While patterns in species richness are relatively well known, especially in coastal and pelagic waters, genetic and ecosystem diversity is less well documented (Fautin *et al*., 2010).

The major threats to biodiversity in temperate marine ecosystems include degradation of habitat, over-exploitation, introduction and spread of invasive species, and climate change impacts (Dulvy *et al*., 2003). In pelagic habitats, three quarters of oceanic sharks and rays are at risk from overfishing (Dulvy *et al*., 2008), while in coastal areas projected losses in seagrass habitats (Short *et al*., 2011) and staghorn corals (Richards *et al*., 2013) are expected to have significant consequences for the distribution and conservation of biodiversity in the North Pacific Ocean. Anticipated responses to climate change include shifts in the distributions of top predators (Hazen *et al*., 2013b) and loss of structurally complex coral reefs (Hoegh-Guldberg *et al*., 2007). The marine biodiversity of plankton in the North Pacific Subtropical Gyre is also changing, likely in response to climate variation (Karl *et al*., 2001).

Since its formation, PICES has recognized the importance of engaging in biodiversity research and has a long history of biodiversity-related contributions. However, the Organization has no formal mechanism to exchange information or provide advice on issues related to biodiversity in the North Pacific despite recent requests to do so, for example, from the Convention on Biological Diversity (CBD)[1] in 2013 (see Appendix 4). Marine biodiversity is important for maintaining ecosystem structure and function which, in turn, supports sustainable fisheries. Understanding the drivers of biodiversity change (*e.g*., non-indigenous marine species, climate change, eutrophication, fishing, pollution, *etc*.) and their interactions can help inform policy makers and managers on decisions related to ecosystem-based management that balance multiple objectives. Other intergovernmental organizations have recognized the need to advance research focused on biodiversity. These include the Strategic Initiative on Biodiversity Science and Advice (SIBAS) within the International Council for the Exploration of the Seas (ICES) and the Medium- Term Strategy within the Northwest

[1] https://www.cbd.int/

Pacific Action Plan (NOWPAP). In addition, the North Pacific Fisheries Commission (NPFC), which includes PICES member countries, recently brought into force a new convention on the conservation of marine resources in the North Pacific Ocean. This convention calls upon member countries to study, conserve and manage vulnerable components of marine biodiversity in international waters of the North Pacific Ocean. Thus, PICES, as a science organization, is well positioned to participate in facilitating the collaborative science needed to address biodiversity priorities in the North Pacific Ocean and to partner with other international organizations such as ICES, NOWPAP, NPFC, CBD, and FAO.

The Study Group on *Biodiversity Conservation* (SG-BC) was approved at PICES-2013 and established in January 2014. The expertise of SG-BC members ranges broadly from invasion biology to climate change, pollution, fishery–habitat interactions, population dynamics, marine spatial planning, risk assessment, ecology of biogenic species, and biodiversity monitoring. The terms of reference (TOR) for SG-BC are to:

1. Review the scope of key drivers of biodiversity change in the North Pacific Ocean, including, but not limited to: non-indigenous marine species, climate change, fishing, and eutrophication;
2. Identify potential mechanisms to advance biodiversity-based scientific research and/or conservation related to drivers of biodiversity change in the North Pacific Ocean;
3. Review the research activities, past and present, undertaken by PICES and other international organizations on biodiversity in the North Pacific Ocean;
4. Identify opportunities for collaboration, new research opportunities for PICES, and the potential to provide science-based advice that could be used to inform decisions related to the conservation and management of biodiversity in the North Pacific Ocean;
5. Prepare a final report that includes an assessment of the merits of establishing an expert group focused on biodiversity science within PICES, and provide recommendations on the role(s) of such a group.

SG-BC activities

In February 2014, SG-BC began proposing ideas related to the five items in SG-BC's TOR to lay the foundation for the structure and content of the SG report. Preliminary ideas and topics for biodiversity science were submitted by SG members from Canada, China, Korea, Russia, and the United States (see Appendix 2 for list of members). The review of research activities, past and present, undertaken by PICES and other international organizations on biodiversity in the North Pacific Ocean was completed (TOR 3). SG members prepared summaries of their country perspectives on: 1) the key drivers of biodiversity change in the North Pacific Ocean, 2) biodiversity research initiatives undertaken by their country, 3) important knowledge gaps, and 4) key scientific questions related to drivers of biodiversity change and biodiversity conservation that could be addressed through PICES (TOR 1).

The SG-BC meeting took place on October 18, 2014 during PICES-2014 in Yeosu, Korea (see Appendix 3 for the business meeting report). Represented at the meeting were Canada (Dr. Janelle Curtis), Korea (Dr. Wongyu Park, Dr. Jae Hoon Noh, Dr. Charity Lee (observer)), the U.S. (Dr. Tom Hourigan, Dr. Chris Rooper), and PICES Science Board (Dr. Thomas Therriault (Science Board Chair)). In addition, written submissions were prepared by members from China (Dr. Jingfeng Fan) and Japan (Dr. Takeo Kurihara, Dr. Ryogen Nanbu) who were unable to attend.

The 1-day meeting began with a review of SG-BC activities and progress to date, a review of PICES past and present activities related to biodiversity conservation, and member country perspectives on the key drivers of biodiversity change and important knowledge gaps that PICES could address. The afternoon was spent reviewing the list of drivers of biodiversity change, identifying key research questions that could be addressed by a new PICES expert group, and drafting recommendations on the roles that such a group could fulfill. The recommendations were based on a gap analysis and a set of evaluation criteria. Action items were identified for completion of the final report.

Significant progress has been made on all five TOR.

Completion of TOR 1. *Review the scope of key drivers of biodiversity change in the North Pacific Ocean*

SG-BC reviewed and drafted summaries of key drivers from PICES member country perspectives, as well as conducted a general review of published literature. Key drivers were grouped into six themes (Table 1):

- Climate change,
- Pollution,
- Fishing,
- Coastal development,
- Non-indigenous species,
- Ecological factors.

SG-BC also noted the importance of interactions among multiple drivers. When compared to the topics addressed by past and present PICES expert groups, the SG noted less activity investigating responses to ecological factors that influence spatial and temporal patterns in biodiversity, and fishing (over-exploitation, bycatch, seafloor contact, changes in ecosystem structure and function).

Table 1 Key drivers of change in biodiversity identified by SG-BC members cross-referenced with PICES past and present activities.

Driver	Commonality among PICES member countries*	PICES past activities	PICES present activities
Climate change	6/6	WG 16; WG 25; SG-FERRRS; CCCC	WG 27; WG 29; S-CCME; FUTURE; AP-COVE
Pollution	5/6	SG-MP; WG 2, WG 15	WG 31; S-HAB
Fishing	4/6	–	–
Coastal development	4/6	–	AP-AICE
Non-indigenous species	3/6	–	WG 21
Ecological factors	3/6	–	–
Multiple stressors	1/6	–	WG 28

*Commonality among PICES member countries indicates the number of countries that identified a driver or stressor within the theme during their review.

SG-FERRRS = Study Group on *Fisheries and Ecosystem Responses to Recent Regime Shifts* (2003–2004)
SG-MP = Study Group on *Marine Pollutants* (2011–2013)
WG 2 = Working Group on *Development of Common Assessment Methodology for Marine Pollution* (1992–1994)
WG 15 = Working Group on *Ecology of Harmful Algal Blooms (HABs) in the North Pacific* (1999–2003)
WG 16 = Working Group on *Climate Change, Shifts in Fish Production, and Fisheries Management* (1999–2005)
WG 21 = Working Group on *Non-indigenous Aquatic Species* (2005–2013)
WG 25 = Joint PICES/ICES Working Group on *Forecasting Climate Change Impacts on Fish and Shellfish* (2008–2011)
WG 27 = Working Group on *North Pacific Climate Variability and Change* (2011–2015)
WG 28 = Working Group on *Development of Ecosystem Indicators to Characterize Ecosystem Responses to Multiple Stressors* (2011–2015)
WG 29 = Working Group on *Regional Climate Modeling* (2011–2015)
WG 31 = Working Group on *Emerging Topics in Marine Pollution* (2014–2016)
S-HAB = Section on *Ecology of Harmful Algal Blooms in the North Pacific* (2003–
S-CCME = Joint PICES/ICES Section on *Climate Change Effects on Marine Ecosystems* (2011–
CCCC = Climate Change and Carrying Capacity program (1995–2009)
FUTURE = **F**orecasting and **U**nderstanding **T**rends, **U**ncertainty and **R**esponses of North Pacific Marine **E**cosystems program (2009–
AP-COVE = FUTURE Advisory Panel on *Climate Ocean Variability and Ecosystems* (2009–2014)
AP-AICE = FUTURE Advisory Panel on *Anthropogenic Influences on Coastal Ecosystems* (2009–2014)

Completion of TOR 2. *Identify potential mechanisms to advance biodiversity-based scientific research and/or conservation related to drivers of biodiversity change in the North Pacific Ocean*

SG-BC identified a broad range of mechanisms to advance biodiversity-based research in the North Pacific Ocean. These include mechanisms related to coordination of information management, analyses, and resources.

Information management
- Construction of regional databases of biodiversity, including indicator species and habitats.

Analyses
- Development of monitoring programs and rapid response plans to detect and manage changes in biodiversity and the distribution of non-indigenous species;
- Development of species distribution models for indicator species and biodiversity indices;
- Development of uniform biodiversity measures that can be compared among ecosystems in the North Pacific region;
- Identification of pathways of effects (*e.g*., vectors of non-indigenous species introductions);
- Development of risk assessment tools;
- Development of genetic tools to quantify population connectivity for key taxa;
- Development of ecosystem models that can predict the effects of human activities or climate change on biodiversity (*i.e*., EcoPath, EcoSim models).

Resources
- Identification of planned biodiversity research expeditions that may benefit from international participation or information dissemination.

Progress on TOR 3. *Review biodiversity activities of PICES and other organizations* and
TOR 4. *Opportunities for collaboration, new avenues of research, and provision of science advice*

SG-BC members compiled a list of key knowledge gaps that were identified as priorities from PICES member country perspectives, as well as research questions relevant to PICES. These were grouped into five research themes (Table 2), although some questions could be grouped with multiple themes. The five themes were:
1. Establishment of baseline inventories of biodiversity, including species and habitats;
2. Analyses to understand and predict spatial patterns in species or habitat distributions;
3. Monitoring to understand drivers of temporal trends in biodiversity;
4. Vulnerability assessment of species and habitats;
5. Analytical methods for marine spatial planning and ecosystem-based management.

The SG cross-referenced these themes with PICES past and present activities and concluded that most knowledge gaps and questions identified by SG-BC have not yet been quantitatively investigated by PICES expert groups. However, SG-BC noted that three expert groups (Working Group on *Ecosystem-based Management Science and its Application to the North Pacific* (WG 19), Working Group on *Non-indigenous Aquatic Species* (WG 21), Working Group on *Development of Ecosystem Indicators to Characterize Ecosystem Responses to Multiple Stressors* (WG 28)) have addressed biodiversity questions (*e.g*., identification of biodiversity indicators), and a PICES Special Publication (CoML Report: Marine Life in the North Pacific: The Known, Unknown, and Unknowable, PICES Special Publication 2, 2005) provides a summary of species diversity and richness in the North Pacific Ocean basin.

Table 2 Key biodiversity research themes identified by PICES member countries cross-referenced with topics addressed by PICES past and present expert groups.

Biodiversity research themes	Commonality among PICES member countries*	PICES past activities	PICES present activities
Establish baseline inventory of biodiversity (species, habitats) • Survey meio- and microbenthos, • Survey bathyal and abyssal depths, • Survey seamounts, hydrothermal vents, coldwater seeps, abyssal plain and rocky trenches, • Delineate benthic and pelagic biogeographic zones	4/5	CoML/PICES Special Publ. 2	–
Understand and predict spatial distribution of biodiversity • Develop predictive models for key indicator species, biogenic habitats, and diversity, • Identify environmental factors that influence biodiversity patterns, • Identify ecological interactions that influence biodiversity patterns	4/5	–	–
Understand and predict temporal variation in biodiversity • Develop indicators to detect change, • Monitor coastal ecosystems (mudflats, coral reefs, mangrove forests), • Monitor marine protected areas (MPAs), • Identify ecological interactions that influence biodiversity patterns	3/5	WG 21	WG 28
Vulnerability assessment • Assess status of biodiversity, • Assess vulnerability to climate change, • Assess susceptibility to anthropogenic activities, • Assess risk of non-indigenous species	3/5	WG 21	–
Analytical methods for biodiversity conservation • Apply criteria for VMEs/EBSAs, • Identify reference points for indicators, • Measure value of biodiversity, • Define principles for MPA networks, • Evaluate MPA performance, • Define appropriate scales for biodiversity conservation	3/5	–	S-HD

*Commonality among PICES member countries indicates the number of countries that identified a knowledge gap or research opportunity within the theme during their review (pending submission from one PICES member country).
WG 21 = Working Group on *Non-indigenous Aquatic Species* (2005–2013)
WG 28 = Working Group on *Development of Ecosystem Indicators to Characterize Ecosystem Responses to Multiple Stressors* (2011–2015)
S-HD = Section on *Human Dimensions of Marine Systems* (2011–2020)
VME = vulnerable marine ecosystem
EBSA = ecologically and biologically significant area

Progress on TOR 5. *Advice to PICES on merits and roles of a biodiversity expert group*

There was strong support among the SG members to establish a PICES expert group on biodiversity. However, the breadth of knowledge gaps and research priorities identified would not be feasible to address within the timeframe of a single expert group. Therefore, the SG devised a list of criteria by which to evaluate the merits of potential research avenues where the research activity:

- Addresses key drivers of biodiversity change;
- Addresses knowledge gaps common to the majority of PICES member countries;
- Is clearly linked to the work of existing PICES expert groups, but
- Avoids duplication in effort by past and present PICES expert groups, and
- Avoids duplication in effort by existing PICES member country initiatives;
- Is narrowly focused to ensure efficiency and feasibility;
- Is achievable with available resources;
- Provides a model for undertaking further biodiversity research within PICES;
- Provides scientific information with clear management application(s).

In addition, SG-BC members preferred options that would lead to a new scientific product. Several ideas were discussed, and three options (Table 3) were evaluated against the following criteria:

a. *Establishment of a network of ocean observation sites for characterizing and monitoring changes in the distribution, abundance and diversity patterns of indicator species (e.g., microbial communities, plankton, and nekton)*. Patterns in distribution and diversity would be correlated with environmental variables to identify key drivers of change and potential predictors. It was noted that the Kuroshio influences the species distributions of five member countries (China, Korea, Japan, Russia and U.S.), and potential observation sites were proposed along the current as well as in the Northeast Pacific Ocean.

b. *Development of guidance on methods for monitoring changes in marine biodiversity*. Guidance could address questions related to selection of indicator species, standards for data collection and analysis of temporal trends, advice on the distribution and networking of monitoring sites, and development of a standard ecological or habitat classification system. This would lay a framework for future PICES research related to assessment and monitoring of marine biodiversity in the North Pacific Ocean.

c. *Mapping known and predicted distributions of structure-forming species (or biogenic habitats) throughout the North Pacific Ocean and relating patterns in distribution and diversity to potential drivers of biodiversity change*. Structure-forming species were viewed as important indicators of biodiversity and are of international conservation interest. This proposal was viewed as added value in that PICES expert groups have not previously focused on deepwater (*i.e.*, >100 m depth) benthic habitats/ecosystems or structure-forming organisms. SG members also recognized the added value of forming a working group with technical expertise in methods for developing and applying predictive models of species distributions, habitats, and biodiversity. Clear scientific products were identified (see Appendix 3, Annual Report of the Study Group on *Biodiversity Conservation*, *SG-BC Endnote 4*) and these could be readily used by other international organizations as inputs for developing management advice.

There was consensus among SG-BC members to develop a proposal to establish a new biodiversity working group to focus research on option c, the distribution and diversity of structure-forming species in the deep waters of the North Pacific Ocean, but to recommend that PICES also consider undertaking options a and/or b in the future. Option c would also address key knowledge gaps identified by China in their report submitted prior to SG-BC's meeting.

Table 3 Evaluation of three research avenues for a new expert group on biodiversity.

Evaluation criteria	Option a: Plankton/nekton biodiversity observation network	Option b: Technical guidance on monitoring biodiversity	Option c: Diversity and distribution of biogenic habitat
Research on drivers of biodiversity change	Yes: climate change, pollution	No	Yes: climate change
Addresses common knowledge gaps identified in review	Yes: predictors of distribution; biodiversity indicators	No	Yes: deep-sea species; benthic habitats; predictors of distribution, biodiversity indicators
Clear linkages to PICES expert groups	Yes: BIO	Yes	Yes: WG 28; BIO
New PICES research	Probably not	Yes	Yes: new focus on benthic habitat
Narrow focus	Yes	Yes	Yes
Scientific paper(s)	Yes	Technical report	Yes
Achievable	Yes	Yes	Yes
Clear applications	No	Yes	Yes

Preliminary feedback from the MEQ, BIO, and FIS committees on the proposal to establish a new working group on biodiversity of biogenic habitats

SG-BC addressed key suggestions from MEQ, BIO, and FIS in revising terms of reference for a new working group.

MEQ:
- The working group should consider the influence of ocean acidification, in particular, aragonite saturation, on the outlook for corals in North Pacific Ocean;
- A focus on the deep sea may exclude data contributions from some countries;
- FUTURE has a focus on coastal ecosystems, through AP-AICE, but is being restructured.

BIO:
- Focus on biogenic habitats, with an emphasis on coral and/or sponge distribution and diversity;
- Deepwater coral and sponge information is an important knowledge gap;
- A broader focus could include other types of biogenic habitats (*e.g.*, seagrass, kelp, oyster reefs);
- Develop a yearly plan, and shorten the proposal;
- Biodiversity indicator work has strong linkage with WG 28.

FIS:
- Deepwater coral and sponge information is an important knowledge gap;
- Focus on deepwater biogenic habitat to narrow the scope;
- Identify expert members and data sources;
- Consider deferring until after FUTURE is restructured.

Based on the above feedback, SG-BC revised its draft proposal and presented it to Science Board on October 24, 2014.

Final report

The following sections address the SG-BC's terms of reference (Appendix 1) and provide additional recommendations on potential avenues of research for PICES to pursue in the short to medium term.

2 Key Drivers of Biodiversity Change in the North Pacific Ocean

This section provides a list of drivers of biodiversity change in the North Pacific Ocean identified by each PICES member country, biodiversity research that has been undertaken or is underway by each country, and important knowledge gaps that could be addressed through collaborative research within PICES.

2.1 Canadian perspective

Contributed by:

Janelle M. R. Curtis
Fisheries and Oceans Canada

In Canada, the federal department of Fisheries and Oceans Canada (DFO) leads scientific research related to the conservation and management of marine biodiversity and in support of Canada's *Species at Risk Act* (SARA), the *Oceans Act*, and the *Fisheries Act*, among other regulatory and policy frameworks. Scientific research is undertaken in collaboration with other federal departments (*e.g.*, Canadian Wildlife Service, Parks Canada Agency, Environment Canada), with the provinces, academic partners, industry, and in many instances, other nations.

Key scientific research programs that currently address biodiversity in marine ecosystems are the Strategic Program for Ecosystem-based Research and Advice (SPERA),[2] the Species at Risk Program,[3] the National Conservation Program,[4] the Aquatic Climate Change Adaptation Services Program (ACCASP)[5] and the International Governance Strategy (IGS).[6] Together, these research programs address scientific questions related to key drivers of biodiversity change in Canada's Pacific Region, including:

- Exploitation of target species;
- Other fishery impacts, including bycatch of vulnerable species, damage or mortality of biogenic organisms, and alteration of ecosystem structure and function;
- Habitat damage, fragmentation and loss;
- Introduction, establishment and spread of aquatic non-indigenous species, including the transfer of novel microbes/pathogens/disease to wild populations;
- Climate change and environmental forcing;
- Eutrophication;
- Hypoxia;
- Ocean acidification;
- Protection of critical habitat for threatened and endangered species;
- Implementation of marine protected areas (MPAs) and conservation areas;
- Identification and management of sensitive benthic areas, ecologically and biologically significant areas (EBSAs), and vulnerable marine ecosystems (VMEs).

Interactions and cumulative impacts of multiple stressors are also recognized as potentially having a disproportionate impact on biodiversity.

Biodiversity research initiatives undertaken by Canada

Research priorities that are targeted by SPERA centre on identifying and assessing threats to aquatic ecosystems, developing tools and methodologies to monitor and assess ecosystems, and developing tools for mitigating stressor impacts and implementing ecosystem-based management. Identification of threats to aquatic ecosystems is carried out through the development of pathways of effects models,

[2] http://www.dfo-mpo.gc.ca/science/rp-pr/spera-psrafe/index-eng.asp
[3] https://www.ec.gc.ca/nature/default.asp?lang=En&n=FB5A4CA8-1
[4] https://www.canada.ca/en/services/environment/conservation/oceans.html
[5] http://www.dfo-mpo.gc.ca/science/rp-pr/accasp-psaccma/index-eng.asp
[6] http://www.dfo-mpo.gc.ca/science/rp-pr/igs-sgi/index-eng.asp

consideration of multiple stressors and cumulative impacts, and the development of risk-based frameworks. Research related to ecosystem monitoring and assessment is focused on the development of methods to select areas for monitoring ecosystems, protocols for effective monitoring, identification of thresholds for informing management decisions, identification of important species and habitats, identification of ecosystem goods and services, and analyses of tradeoffs and species interactions. Tools for implementing ecosystem-based management include of applications of GIS software and spatial analysis tools to classify seabed features and habitats, and to map biodiversity. Recent biodiversity-related research in the Pacific Region includes the development of a rapid screening tool for marine fish based on the Australian Ecological Risk Assessment Framework (ERAF), and the application of an ERAF for management of large ocean management areas and MPAs. Research initiatives that are currently supported through SPERA in Canada's Pacific Region include research related to understanding the impacts of drivers of biodiversity change, classifying areas according to their ecological attributes as well as ecological and biological significance, developing frameworks to inform marine spatial planning decisions, and evaluating the effectiveness of conservation measures. Specifically, current studies in SPERA focus on:

- Impacts of future hypoxia in British Columbia;
- Changes in biodiversity, species distribution, behaviour, abundance and interactions in response to environmental forcing;
- Impacts to the community structure and ecosystem function of the Pacific glass sponge reefs;
- EBSAs between the shelf break and Canada's boundary with the exclusive economic zone;
- Development of a systematic hierarchical marine ecological classification system for use in marine spatial planning and MPA network design;
- Ecosystem indicators and thresholds to inform marine ecosystem approach to management and objectives assessment in the Gwaii Haanas National Marine Conservation Area Reserve;
- Effectiveness of Rockfish Conservation Areas in British Columbia.

Two national science-based research programs focus strategically on the assessment, conservation and recovery of threatened and endangered species and their habitats (Species at Risk Program), and the assessment, monitoring and management of aquatic invasive species. In addition, Canada recently launched its National Conservation Plan which focuses in part on monitoring and management of MPAs.

The current scientific research priorities for ACCASP centre on understanding climate change impacts on Canada's oceans and inland waters, developing and applying tools for incorporating climate change considerations into management of aquatic ecosystems, and supporting decisions that have been identified as being particularly sensitive to the impacts of a changing climate. Sensitive decisions related to biodiversity include determining the recovery potential and critical habitat of species at risk and developing management measures needed to conserve areas within existing and future MPAs and MPA networks. Adaptation tools identified as priorities for development include science-based vulnerability indices for species at risk, fish habitats, and marine protected area networks. Current biodiversity research underway in the Pacific Region centres on developing and applying a vulnerability assessment framework with an emphasis on pelagic fishes.

Canada's IGS addresses key scientific research needed to support decisions in the context of international policies, guidelines, and commitments. Priorities addressed by the IGS program include scientific research to support decisions related to new regional fisheries management organizations (RFMOs), management of transboundary stocks, governance initiatives related to climate change and variability, implementation of ecosystem-based fisheries management, implementation of United Nations resolution 61/105 and related Food and Agriculture Organization (FAO) and Convention on Biological Diversity (CBD) decisions, and development of new standards and tools. Key biodiversity agreements or guidelines addressed by IGS research include those advanced by the United Nations General Assembly (UNGA) Resolution 61/105, FAO International Guidelines on the Management of Deep Sea Fisheries in the High Seas; CBD X/29 paragraph 48, FAO Guidelines on bycatch management, the World Summit on Sustainable Development (WSSD), and the North Pacific Fisheries Commission, a new RFMO that has recently (July 2015) implemented the Convention on the Conservation and Management of High Seas Fisheries Resources in the North Pacific Ocean.

Biodiversity-related research priorities identified through the IGS program and relevant to the Pacific Region centre on identification of current and potential impacts to areas or species vulnerable to ocean acidification, identification and mapping of VMEs and EBSAs, research in support of identification of significant adverse impacts, ecological impacts of bycatch, MPA network design, and understanding key processes and influences on biodiversity (structure, function and productivity). Biodiversity research currently underway in the Pacific Region includes development of a species inventory and assessment of the distribution of VME components and observable fisheries impacts on Cobb Seamount.

Canada recently participated in international workshops led by the Convention on Biodiversity Secretariat and FAO to identify EBSAs (Moscow, Russian Federation, March 2013, and to discuss approaches to identify VMEs in the North Pacific Ocean (Tokyo, Japan, March 2014), respectively.

Key knowledge gaps

A review of recent requests for science advice submitted to DFO's Centre for Science Advice in the Pacific Region provides a useful insight into additional important gaps in scientific knowledge related to biodiversity conservation. Recent requests related to biodiversity centred on:

- Assessing the risks associated with the transfer of species, including the establishment of non-indigenous fauna and flora, transfer of microbes, pathogens or disease between wild and cultured fish, and transfer of hatchery-derived shellfish among management zones;
- Assessing impacts of fisheries and aquaculture on benthic communities within and outside existing or proposed MPAs;
- Assessing the status of commercially exploited species as well as the status and recovery potential of threatened or endangered species;
- Developing a strategy for monitoring responses to potential oil spills;
- Mapping important species, habitats and areas, including listed species at risk, critical habitat for species at risk, and EBSAs;
- Prioritizing areas for biodiversity conservation, including important areas (IAs), EBSAs, and commercial no-take reserves for shellfish;
- Identifying indicators for monitoring MPAs and for integrated management of marine ecosystems.

Other outstanding biodiversity questions include:

- How does the function of special ecosystem features vary with their quantity, quality, and spatial pattern?
- What are the effects of overfishing, including bycatch, on trophic structure, predator–prey relationships, and fish assemblages?
- What is the value of ecological goods and services of MPAs, EBSAs, and ecologically significant species?
- How should the principles of connectivity, replication and adequacy/viability be applied in the context of marine spatial planning and conservation?
- What are the appropriate scales for conservation of biodiversity?

2.2 Chinese perspective

Contributed by:

Jingfeng Fan and Guoxiang Liao
State Oceanic Administration

Key drivers of biodiversity change in the North Pacific

Against a background of declining global biodiversity, the situation for marine biodiversity in China is not optimistic. China has an extensive coastline, 18,000 km in length, ranging from the temperate to tropical climate zones. China, with a distribution of most marine ecosystem types, is one of the countries with the richest marine biodiversity in the world. To date, China has recorded 28,000 marine species (Yu *et al.*, 2015), accounting for about 11% of recorded marine species in the world. The number of recorded marine species in China ranks third in the world, after Australia and Japan, which makes China an important marine biodiversity country.

With the rapid development of industrial production in coastal cities, an increase in the intensity of fishing activity in the inner shelf area, and a corresponding rise in environmental pollution and decline of living resources, the high biodiversity and richness of marine species and living resources in the China seas have seriously decreased. Sustainable fishery production is difficult. China has fully exploited the living resources of its coasts and continental shelf, and many species of China's coastal areas are over-exploited. Examples are the large yellow croaker *Larimichthys crocea*, the Chinese shrimp

Fenneropenaeus chinensis, and the cuttlefish *Sepiella japonicus*, for which captures in recent years have decreased significantly due to population decline and collapse.

Besides the over-exploitation of fishery resources, another major threat to the biodiversity of the China seas is environmental deterioration (pollution, coastal construction), particularly in the brackish waters of estuarine environments which are characterized by high productivity and provide spawning and nursery areas for several species.

In the long term, climate change is also a major threat. To maintain and conserve the highly diversified marine biota and rich living resources of the China seas, the government of China has adopted laws and regulations for their conservation and at the same time has established many natural conservation areas (reserves) and areas or periods of time in which fishing is forbidden. Various research projects have been approved and financially supported.

Changes in the biodiversity of various habitats such as intertidal mud flats, coral reefs, and mangrove swamps have been monitored and studied. An assessment of endangered species of major vertebrate groups (mammals, amphibians and reptiles, birds, and fishes) was published in the *China Red Data Book of Endangered Animals* in the 1990s. More recently, a new Red List of plant and animal species (terrestrial, freshwater, and marine) has been published, based on historical as well as new data, with the threatened category of species assessed using new IUCN (International Union for Conservation of Nature) criteria. Since 2004, the *China Species Red List* has documented an increasing number of species endangered by the impact of human activities (mainly over-exploitation and environmental pollution) and by global climate change. The *China Species Red List* is not encouraging, as many marine species are regarded as "endangered" because of over-exploitation for the seafood market or for "fine art" collections.

To protect marine biodiversity, many countries and international organizations have carried out research and action plans for biodiversity protection at global, regional and national levels in recent years, including the Convention on Biological Diversity, International Biodiversity Program, Millennium Ecosystem Assessment, and Census of Marine Life. As a participating country in multiple plans, China has carried out a large number of ecological protection and construction works in the last 10 years.

Biodiversity research initiatives undertaken by China

A comprehensive systematic study of marine biodiversity in China began in the early 1950s with the establishment of the Qingdao Marine Biological Laboratory of the Chinese Academy of Sciences. Since that time, scientists have carried out intensive multidisciplinary research on marine life in China's seas and have recorded 22,629 species belonging to 46 phyla. The marine flora and fauna of the China seas are characterized by high biodiversity, including tropical and subtropical elements of the Indo-West Pacific warm-water fauna in the South and East China seas, and temperate elements of North Pacific temperate fauna, mainly in the Yellow Sea. The southern South China Sea fauna is characterized by typical tropical elements paralleled with the tropical faunal center of the Philippine–New Guinea–Indonesia Coral triangle.

The seas surrounding mainland China and its southern islands and reefs span 38 degrees of latitude (3°–4°N) from the tropical to the warm-temperate climate zones, and include the widest continental shelf in the Eastern Hemisphere. Under the influence of the strong Kuroshio Warm Current, the South China Sea Warm Current, and the Taiwan Warm Current, the water temperature of the East and South China seas is comparatively high, warmer than 14°–16°C in coastal areas in winter. The marine flora and fauna of the China seas are rich in warm-water species, comprising tropical and subtropical elements of the Indo-West Pacific Biotic Region, with high dominance of some endemic and economically important species, mainly endemic to the East China Sea and neighboring waters. The tropical Indo-Malaysian biotic elements that are transported by these warm currents originate in the south, while the cold-water species come from the north and dominate the deeper parts of the Yellow Sea Cold Water Mass under the thermocline at the 15–30 m layer in summer. Thus, the China seas are characterized by high biodiversity, including particularly rich tropical and subtropical elements in the East and South China seas and temperate biota in the Yellow and Bohai seas. However, fewer cold-water species are found in the Yellow Sea than in waters off northern Japan, which is dominated by the strong Oyashio Cold Current, while the number of tropical elements found in the South China Sea is less than that recorded in the Philippine–New Guinea–Indonesia triangle area — the center of tropical Indo-West Pacific Biota. Low temperatures in winter have limited the survival of warm-water species, resulting in low biodiversity. Therefore, among a total of 22,629 Chinese marine species, only 1,607 species live in Yellow Sea. It is noteworthy that the strong Tsushima Current brings some warm-water species as it flows along the west coast of Honshu north to the Tsugaru Strait. Consequently, the number of warm-water species in the eastern Sea of Japan is much greater than in the western Russian waters, where the marine fauna is cold temperate, while the majority of the eastern Japanese fauna is warm temperate. In addition, the number of species in China's seas shows a distinct increase from the north to the south — from high to low latitude.

Important knowledge gaps

Although significant advances have been made in marine biodiversity research in China since the 1950s, through data collection and the formal description of species, much remains to be done. The biogeographic features and habitat of the deep sea and the southern China seas have not been well explored. Taxonomic coverage of many groups, such as those that comprise the meio- and microbenthos — nematodes, harpacticoids, and ostracod crustaceans, *etc*. — is incomplete in our present data, which comes largely from northern Chinese waters. The study of ecosystem structure and function has been particularly neglected in "the utmost environment" — the Yellow Sea Cold Water Mass — which is considered a refuge for North Pacific Temperate Fauna. Exploration and study of the bathyal and abyssal depths of the South China Sea, including sea mountains, hydrothermal vents, and cold-water seeps, as well as the abyssal plain and rocky trenches, should be strengthened.

Key scientific questions related to drivers of biodiversity change and biodiversity conservation that could be addressed through PICES

Key research objectives that could be addressed by PICES include:

- Strengthening the collection of materials (specimens) for marine biodiversity study by carrying out a biodiversity background value survey and deep-sea collection cruises to discover new species and reveal the past and present abundance of major species and biological communities while forecasting their future. Intensive collections and study of deepwater marine biodiversity should be made to discover new species and to reveal past, present, and future trends of major species and biological communities;
- Carrying out biodiversity monitoring surveys in various habitats to assess their present status and to understand the processes and mechanisms of global climate change and human activities that have an impact on biodiversity;
- Strengthening basic research on change of marine biodiversity, particularly the assessment and conservation of biodiversity and endangered species for sustainable development;
- Minimizing the disparity between the study and conservation of marine and terrestrial (including freshwater) biodiversity, and effective management. To achieve this, early career scientists, especially taxonomists, should be trained to study different biotic groups systematically;
- Strengthening conservation management to achieve more effective management of fisheries resources.

2.3 Japanese perspective

Contributed by:

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Fisheries Research Agency

Possible drivers of biodiversity change in the North Pacific

We collected key reports and papers regarding marine biodiversity in the coastal area of Japan (at large spatio-temporal scales, mainly > 10 km and/or > 10 yr). They consist of four monitoring programs for biodiversity and eight studies on key drivers of biodiversity change cited below in *Biodiversity research initiatives*. The information suggests that the key drivers of biodiversity change include climate change, eutrophication, oil spills, and hypoxia. In addition, previous studies on biodiversity in other countries suggest many factors, including spatial heterogeneity of abiotic environments, existence of species pools, interspecific facilitation and competition, predation, and food abundance.

Biodiversity research initiatives in Japan

The following lists key reports and scientific papers on biodiversity in the coastal area in Japan. They include monitoring studies and studies of factors leading to spatio-temporal changes in biodiversity.

Ohgaki and Tanase (1984 a, b)
Study site: Rocky shores, Hatakejima Island, Wakayama Prefecture
Method: Record of intertidal animals conducted by students and researchers since 1949.

Association for the Research of Littoral Organisms in Osaka Bay (2002)
Study site: Rocky shores, Osaka Bay, the Seto Inland Sea
Method: Record of intertidal rocky-shore organisms conducted by researchers and volunteers since 1980.

Gamo Higata Shizen Saisei Kyogikai (2008; the sampling design is not fully detailed)
Study site: Gamo sand flat, Miyagi Prefecture, Tohoku
Method: Core sampling of epibenthic and endo-benthic organisms from 1989–2014.

Wetlands International Japan (2014)
Project name: Monitoring 1000
Scheme: Probably the biggest biodiversity monitoring project in Japan at present, which aims for the long-term monitoring of 1,000 sites throughout Japan (both terrestrial and aquatic ecosystems).
Method: Sampling methods are diverse; started in 2003.

Ohgaki et al. (1997)
Study site: Rocky shores, Hatakejima Island, Wakayama Prefecture
Method: Semi-quantitative evaluation of intertidal animal density. Comparisons made between 1969 *vs*. 1983–1984 *vs*. 1993. Variation in abundances of warm-water species and indicator species of eutrophication was found in parallel with fluctuation of water temperature and indices of nutrient levels.

Ohgaki et al. (1999)
Study site: Rocky shores, Bansho Cape, Wakayama Prefecture
Method: Semi-quantitative evaluation of density of intertidal mollusc density from 1985–1994.
Results: Increases in species richness and distribution range were found for southern species in parallel with rising temperature and increasing proximity of the Kuroshio Current to the study site.

Kanazawa et al. (2005)
Study site: Ariake Sea, Kyushu
Method: Grab sampling of bivalves.
Results: Decreased species richness was found after the construction of a dike for the reclamation of Isahaya Bay.

Kawai et al. (2007)
Study site: Rocky shores, Hyogo Prefecture, Sea of Japan
Method: Record of percent cover of macro-algae in quadrats from 1997–2006 after the Nakhodka oil spill accident.
Results: The high intertidal zone at Imago-ura, where a large part of the stranded oil accumulated, suffered the heaviest damage and experienced the slowest recovery.

Yoshino et al. (2010)
Study site: Ariake Sea, Kyushu
Method: Grab sampling of macrofauna.
Results: Decreased species richness and abundance of some species were found simultaneously with hypoxia.

Kurihara et al. (2011)
Study site: Rocky shores on the Pacific coast of Japan
Method: Quadrat sampling of intertidal molluscs in 1978, 1984–1986, and 2005–2006.
Results: Species richness of warm-water species increased more sharply than that of cold-water species in relation to rising air and water temperatures at the study sites.

Yamano et al. (2011)
Study site: Coral reefs around Japan
Method: Bibliographical survey. Comparison of presence/absence of coral species data around Japan during the 1930s, 1960s–1970s, and 1980–1990s.
Results: Poleward extension of distribution range (*i.e*., increased species richness of corals in the northern sea area of Japan) is related with global warming.

Okuda et al. (2009)
Study site: Rocky shores on the Pacific coast of Japan
Method: Record of occurrence/absence of rocky-shore sessile animals by means of a hierarchically nested sampling design using fixed grids.
Results: Latitudinal gradients of species richness, the pattern of which was dependent on the sampling area, were found. This phenomenon is discussed in relation to "species sorting".

Important knowledge gaps

Although many researchers believe that biodiversity is important, this is not true for many citizens and politicians. To narrow the gap, researchers may need to clarify how biodiversity is useful (especially with regard to the economy). One strategy might be to show how biodiversity has changed in some areas of the sea and how the change has affected the economy related with those areas (*e.g*., fish production, tourism). This strategy does, however, need a large workforce and budget. Therefore, a more realistic strategy is to compare present and previous situations of biodiversity, using previous data, and to estimate the possible economic impact, if possible.

Acknowledgements

We thank very useful information kindly provided by Drs. Masakazu Hori, Gen Kanaya, Taeko Kimura, Masahiro Nakaoka, Takashi Noda, Yoshitake Takada, and Katsumasa Yamada.

2.4 Korean perspective

Contributed by:

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Key drivers of biodiversity change in the North Pacific

We investigated reports and other publications regarding marine biodiversity in Korean coastal and offshore waters (MOF, 2006–2013, 2008–2013). According to this literature and other products from many existing research activities, it is suggested that the key drivers of biodiversity change include climate change, eutrophication, and various factors which are spatially categorized in the following.

Coastal waters

Regional effects

- *Coastal development*: Diversity and habitats of many tidal flats/wetland organisms along the western part of the Korean peninsula is seriously threatened by reclamation and dike constructions which have reduced 36% of the Korean coastal tidal flats in the past 45 years.
- *Eutrophication*: Diversity change is becoming evident as a result of increased coastal eutrophication brought about by increasing coastal aquaculture practices as well as by nutrient flow from rivers or streams.
- *Hypoxia*: Coastal eutrophication is manifested by seasonal hypoxia of the local environment, leading to the disappearance of local species.
- *Pollution*: Rising pollution (chemical and non-chemical) from increasing human activities are impacting species biodiversity and spatial distribution.
- *Over-fishing*: Intense over-fishing is endangering many important commercial fisheries as well as general fish species caught as fisheries byproduct.

Global effects

- *Global warming*: There is increased reporting on warm-water indicator species along Korean coastal waters, mostly likely owing to increasing water temperature due to global environmental changes.

- *Whitening/bleaching events*: These events are being observed more frequently, and in wider areas, most likely due to increasing water temperature and/or increasing pollutants. These expanding whitening events are impacting diversity changes of algae species and therefore, the herbivores feeding on them.

Off-shore waters

- *Global warming*: The distribution scale of warm-water species is affected by increasing sea surface temperature.
- *Ocean acidification*: The distribution and diversity of marine calcifiers are expected to be impacted by global ocean acidification.

Biodiversity research initiatives in Korea

Basic tools for the understanding, conservation, and management of biodiversity is evaluation and monitoring using survey works. In Korea, the results of such marine biodiversity surveys have been used as a basic framework for evaluation measures for conservation policy making.

The Ministry of Oceans and Fisheries (previously known as the Ministry of Maritime Affairs and Fisheries) enacted the *Conservation and Management of Marine Ecosystems Act* in 2006. This *Act* includes several research projects such as the National Investigation of Marine Ecosystem, National Wetland Survey, Marine Protected Area Survey (21 sites), and Marine Biological Resources Survey.

The National Fisheries Research and Development Institute (NFRDI) has carried out a National Serial Oceanographic Survey since 1965. The main surveys are usually divided into several sections of the maritime area and are conducted at intervals of seasons or months. Results from marine species surveys found up to 9,534 species, including 6,110 (64.1%) animal species, 1,048 (11.0%) plant species, 2,172 (22.8%) phytoplankton species, and 204 (2.1%) zooplankton species in the Korea marine ecosystem. Among those species, 1,141 (955 animal species and 186 plant species) are found along coastal wetlands.

Knowledge gaps

In Korea, the main reasons for biodiversity decrease are habitat destruction, eutrophication and other factors caused by increasing human activity. Based on these observations, the government of Korea has been conducting a biodiversity survey of coastal ecosystems, as stipulated in its related *Acts* and regulations, along Korean coastal waters at every 10-year period. These surveys also help to gather other coastal environmental data and related factors of diversity. However, it is not easy to clarify the key drivers of biodiversity even with the accumulated information because there are not enough regional and spatial baseline data for biodiversity from the current set of data to estimate current biodiversity richness or poorness. So the first challenge is to identify the baseline *status quo* from which trends in marine biodiversity change could be detected at the relevant spatial and temporal scales.

Climate change is expected to be one of the major environmental challenges of the 21st century, and various models predict a 2–4°C rise in water temperature in the current century. On-going climate change will likely cause shifts in the diversity and productivity of marine organisms due to the expansion of subtropical conditions and the simultaneous shrinking of polar environments (Sarmiento *et al*., 2004; Polovina *et al*., 2011; Chust *et al*., 2014).

In Korean waters, the impacts of increasing water temperature will provide an ecosystem more suitable to subtropical organisms of various taxonomic groups, and there are now increasing reports of such observations in the Korean marine ecosystems. However, the waters surrounding the Korean peninsula are strongly influenced by warm currents branching out from the north equatorial current and Kuroshio current. Such warm water currents act as a conveyor belt entraining subtropical species northward into Korean waters. Therefore, a preliminary assessment of observed warm water subtropical species needs to be determined as to whether they have been carried in by warm water currents or are due to climate change processes. When that information has been collected, then a more accurate assessment can be carried out for observed subtropical species.

Usually, exotic species have been introduced by man and by unknown passages. Many non-native species have been introduced for commercial purposes, including ornamental uses, and some have been transported by undesirable methods such as discharged water from ship ballast systems. Some artificially introduced species have been helpful, but most often invasive species, including unexpected species, are ruining the ecosystem by removing endemic species. This observation is often noted in the marine ecosystem. A total 103 introduced species have been reported (MOE, 2012). Of those, 19 species are marine invertebrates. However, any evidence of their ecological impact in the field is barely known. Some of them may change the local biodiversity of their distribution range, but it is also understood that strong knowledge gaps exist on such matters.

Key scientific questions related to drivers of biodiversity change and biodiversity conservation that could be addressed through PICES

It is difficult to judge which biodiversity changes are due to human impact or due to climate change, but most evidence suggests that coastal and open ocean marine species are under heavy pressure in most parts of the world from the following factors:

- Over-exploitation of resources;
- Pollution and eutrophication;
- Introduction of invasive 'alien' species;
- Habitat destruction (*e.g.*, reclamation and grand-scale dike construction);
- Global climate change and ocean acidification.

Therefore, the aforementioned key biodiversity drivers of the Korean marine system and other factors are needed to be reviewed by SG-BC. However, since many activities are within the scope of the SG, a limited and focused study should be decided by the Group:

- Selection of target species for the study after soliciting and collecting opinions from marine ecologists and biologists of each member country, and then reviewed by SG-BC;
- Gathering of global data, or data from each member country, of targeted species after which material will be processed and organized by SG-BC for drawing up the *status quo* current state and results on the future forecasts;
- Exchange of information on biodiversity programs and other research results; such efforts could contribute in the enhancement of research capacity of North Pacific biodiversity.

2.5 Russian perspective

Contributed by:

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The Convention on Biological Diversity was approved by Russia in 1995, and a National Strategy for Biodiversity Conservation was endorsed in 2001.

Key drivers of biodiversity change in the North Pacific

Key drivers of biodiversity change in Russian and adjacent international waters in the North Pacific Ocean include natural–physical, climatic and oceanographic changes, and intra-population processes causing fluctuations in the number of species and the extent of their ranges.

2.6 U.S. perspective

Contributed by:

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The United States has the largest exclusive economic zone in the world, most of it centered around the North Pacific. U.S. Pacific waters stretch from the Eastern Pacific to Guam and the Mariana Islands in the West, including tropical, temperate and polar biomes, and everything from coastal ecosystems to the world's deepest submarine trench. This broad biogeographic extent means that the U.S. shares ecosystems and species with many North Pacific nations and can benefit from a shared understanding of their biodiversity. The U.S. also participates in a number of regional organizations with responsibilities that may have consequences for marine biodiversity. It is the policy of the United States to protect, maintain, and restore the health and biological diversity of ocean and coastal ecosystems and resources (CEQ, 2010).

Key drivers of biodiversity change in the North Pacific

The primary drivers of change in marine biodiversity loss have been identified in numerous documents (*e.g*., NRC, 1995) and include:

- Coastal habitat modification (*e.g*., loss of coastal wetlands, nearshore development, nearshore mining);
- Fisheries impacts, particularly habitat damage from mobile bottom-contact gear (bottom trawls), bycatch, and overfishing;
- Land-based pollution, including chemical pollution and eutrophication;
- Invasive species;
- Climate change, including coral bleaching, changes in species distributions, and impacts on biodiversity from changing currents, sea-level rise, and rainfall/freshwater input patterns;
- Ocean acidification (NOAA Ocean Acidification Steering Committee, 2010), particularly impacts on the calcification by a wide range of organisms, including many keystone species in North Pacific ecosystems.

These stressors have affected, and may yet affect, marine biodiversity from the intertidal zone to the deep sea. With the exception of climate change and ocean acidification, the impacts of these drivers generally become less intense as one moves farther from land. However, fishing impacts in particular are thought to be an important contributor to biodiversity loss in areas beyond national jurisdiction (Worm *et al*., 2006).

U.S. biodiversity initiatives in the North Pacific

The U.S. has significant capacity for marine biodiversity research in the academic and government sectors, and a large number of initiatives that touch on providing information needed to advance conservation of ocean biodiversity in the North Pacific. Most of these are directed toward specific geographies within U.S. waters, or to specific research questions. For the purposes of the SG-BC, we selected a few initiatives that we feel would benefit in particular from collaboration or linkages with other PICES members:

- Marine Biodiversity Observation Network (MBON;[7] Duffy *et al*., 2013). In October 2014, a consortium of U.S. agencies announced three pilot projects, two of which have sentinel sites along the California coast.
- National Oceanic and Atmospheric Administration:
    - Deep Sea Coral Research & Technology Program [8] (Field Research Initiatives in the Northeast Pacific, 2010–2014; U.S. Pacific Islands, 2015–2017), and National Deep-Sea Coral and Sponge Database;
    - Ocean Exploration and Research9 – Various exploration expeditions in the North Pacific, including planned ROV expeditions in 2015–2017;
    - Coral Reef Conservation Program 10 – Coral Reef Biodiversity Monitoring and participation in the Census of Marine Life's Census of Coral Reefs Ecosystems;
    - Ocean Acidification Program 11 – An important area of focus includes studying the biological responses of marine species to changing ocean chemistry. The Program is coordinating internationally to develop a global Ocean Acidification Observing Network (Newton et al., 2012);

[7] http://www.marinebon.org/
[8] http://www.habitat.noaa.gov/protection/corals/deepseacorals.html
[9] http://oceanexplorer.noaa.gov/
[10] http://coralreef.noaa.gov/
[11] http://oceanacidification.noaa.gov/

  - National Marine Sanctuary Program[12] and Pacific Island Marine National Monuments.[13] These programs have the conservation of biodiversity as a primary mandate;
  - National Science Foundation;[14]
- Smithsonian Institution – National Museum of Natural History.[15] The Smithsonian Institution was a principal player in the Census of Marine Life efforts, and its Tennenbaum Marine Observatories are a new effort to develop a worldwide network of coastal ecological field sites, standardizing measurements of biological change.

In addition to these initiatives to study biodiversity, the U.S. is engaged in a large number of collaborations designed to support ecosystem approaches to ocean resource management. Species diversity is a vital component of maintaining healthy, productive and resilient ecosystems that can provide services to the U.S. population. The goal of maintaining healthy and productive fisheries has led NOAA's Fisheries Service to develop monitoring programs that directly measure diversity in the North Pacific. As an example, the species diversity and composition of copepods in the California Current system has been shown to affect the survival and growth of salmon species (Peterson, 2009). Thus, copepod species richness is monitored annually in Oregon and Washington. As another example, the stock assessment and fishery evaluation reports for Alaskan groundfish and crab species provide information useful to monitoring the Alaskan ecosystems (Zador *et al*., 2013). The information includes indicators of biodiversity that are updated annually from existing data collection programs. For example, biodiversity indicators (species richness and evenness) are monitored biennially in the eastern Bering Sea slope using bottom trawl survey data. These data integrate the effects of climate change, ocean acidification and fishing activity and can be used to monitor changes over time.

The U.S. also participates in a number of international activities related to marine biodiversity including:

- The Ocean Biogeographic Information System (OBIS), a global network of regional and thematic (taxon-based) data nodes that is organized within the Intergovernmental Oceanographic Data and Information Exchange within UNESCO's International Oceanographic Commission (IOC). The U.S. node, OBIS-USA,[16] has been a leader in the OBIS activity since it was first proposed for adoption by the IOC. PICES participant countries with OBIS nodes include Canada, China, Korea, Japan, and the U.S.;
- Involvement in global efforts to capture scientific data for use in international fora. As an example, OBIS has been a major contributor to CBD EBSA efforts. Duke University (OBIS SEAMAP) has led several regional workshops on this topic;
- Global Ocean Observing System (GOOS);[17]
- Group on Earth Observations Biodiversity Observation Network (GEO BON).[18]

Important knowledge gaps in scientific information needed to address biodiversity and conservation issues

Biological diversity spans many levels, from intraspecific genetic variation, through species diversity, to ecosystem and habitat-level diversity. The amount of information available at each of these levels and among different categories within each level varies widely. For example, genetic variation within species is known only for a small number of taxa – generally vertebrates of particular economic or conservation interest (*e.g*., salmon). Species richness is known for a broader array of taxa, but abundance measures are often lacking for all but marine mammals, birds, reptiles, and fish species. Ecosystem- or habitat-level diversity can often be crudely approximated, based on certain physical or chemical or ocean measurements, but often lacks metrics for comparing results among different regions (*e.g*., consistent habitat classification systems). In general, knowledge of marine biodiversity also decreases with depth and distance from shore.

In addition to these issues, there is no formal mechanism to implement monitoring, collating of existing data or maintaining ongoing data on biodiversity in U.S. waters. There is also a lack of uniform biodiversity measures that can be compared among ecosystems in the North Pacific region. These are challenges for recognizing changes in

[12] http://sanctuaries.noaa.gov/
[13] http://www.fpir.noaa.gov/MNM/mnm_index.html
[14] http://oceanexplorer.noaa.gov/
[15] http://www.mnh.si.edu/rc/
[16] http://www.usgs.gov/obis-usa/
[17] http://www.goosocean.org/
[18] http://geobon.org/

biodiversity in a timely manner when they may occur. Given these variables, it becomes particularly important to specify the biodiversity or conservation objectives or questions that will be addressed. This will determine the most appropriate biodiversity metrics to answer those questions.

1. *Objective:* Understanding marine biodiversity

- Factors that contribute to local biodiversity (*e.g.*, for specific biomes or habitat types) and their susceptibility to particular anthropogenic impacts. Users: fishery and sanctuary managers;
- Networking pilot projects across the North Pacific.

2. *Objective:* Identifying marine biodiversity priorities for spatial management

- Delineation of benthic and pelagic biogeographic ecoregions in the North Pacific is a first step in identification of regional biodiversity patterns that can help assess how current and proposed management measures (*e.g.*, marine protected areas or spatial gear restrictions) are expected to affect regional biodiversity. These can build upon Spaulding *et al*. (2007) and UNESCO (2009);
- Development of consistent habitat classification schemes for the North Pacific (*e.g.*, FGDC, 2012 or Greene *et al*., 1999);
- Identification of deepwater biogenic habitats vulnerable to impacts from bottom-contact fishing gear:
  - Development of habitat suitability models (*e.g.*, Yeeson *et al*., 2012) for key biogenic habitat-forming species (*e.g.*, corals or sponges);
  - In areas beyond national jurisdiction, this will contribute to the identification of vulnerable marine ecosystems (VMEs) needed to advise the North Pacific Fisheries Commission (NPFC) and prevent serious adverse impacts to VMEs;
  - Identification of ecologically and biologically significant areas (EBSAs) in the deep sea and open ocean in support of the Convention on Biological Diversity (CBD), and specifying commonalities with regional VMEs. There may also be commonalities with the criteria for the International Seabed Authority's "Areas of Particular Environmental Interest" and the International Maritime Organization's "Particularly Sensitive Sea Areas."

3. *Objective:* Identifying biodiversity metrics or proxies for use in monitoring changes due to climate change and ocean acidification

- Identification of reference points for biodiversity indicators for different marine ecosystems;
- Identification of indicators or proxies for marine biodiversity in different ecosystems;
- Development of models to predict the impacts of climate change or ocean acidification on species distribution and biodiversity patterns.

4. *Objective:* Identifying opportunities for international cooperation on biodiversity studies

- Identification of planned biodiversity research expeditions that may benefit from international participation or information dissemination. End users: participating countries and NPFC.

Conclusions

From our perspective, three key questions for the SG are as follows:

1. What could PICES add to existing regional processes or efforts (*e.g.*, science advice to the NPFC)?

2. What added value can be gained by networking biodiversity information at the ocean basin level (*e.g.*, contributing to existing biodiversity database efforts or networking among study sites at similar latitudes)?

3. Can a PICES science effort contribute to identifying biodiversity metrics that could be used at the North Pacific ocean basin level for monitoring impacts of climate change or ocean acidification?

2.7 Summary of drivers, research initiatives and priorities for biodiversity research in the North Pacific Ocean

PICES member countries identified key drivers of biodiversity change in coastal and offshore ecosystems. These include:

Coastal ecosystems

- The introduction, establishment and spread of non-indigenous species leading to loss of species and habitats (*e.g*., *Spartina alterniflora*);
- Overfishing leading to declines in fishery resources, declines in the diversity of fishes, invertebrates, and structure-forming (biogenic) species, and/or degradation or loss of habitat;
- Coastal habitat modification (*e.g*., land reclamation, nearshore development, nearshore mining, beach access) leading to loss of coastal wetlands, mangroves and other ecosystems;
- Land-based nutrient (organic) pollution leading to eutrophication and harmful algal blooms;
- Land-based chemical (inorganic) pollution leading to bioaccumulation of toxins and fitness consequences for a broad range of taxa;
- Hypoxia;
- Sediment runoff;
- Light pollution;
- Fish farming leading to nutrient and other types of pollution;
- Oil spills associated with increased maritime transport;
- Climate change leading to coral bleaching, changes in species distribution and other impacts associated with sea-level rise, and changing currents, temperature regimes, and rainfall/ freshwater input patterns;
- Ocean acidification leading to impacts on calcification;
- Large-scale climatic, ultraviolet radiation, and oceanographic changes leading to impacts on population demography and changes in the number and distribution of species;
- Establishment of MPAs leading to a recovery of biodiversity.

Offshore ecosystems

- Introduction, establishment and spread of non-indigenous species leading to loss of native species and habitats;
- Overfishing leading to declines in fishery resources, diversity of fishes and invertebrates and structure-forming (biogenic) species, and/or degradation or loss of habitat including biogenic structures;
- Deep-sea mining leading to habitat loss (*e.g*., metallic sulfides or cobalt-rich crusts);
- Climate change leading to changes in species distributions, currents, and temperature and rainfall patterns;
- Ocean acidification leading to impacts on calcification;
- Marine pollution (*e.g*., derelict fishing gear, plastics, persistent organic pollutants);
- Oil spills associated with maritime transport and offshore oil exploitation;
- Large-scale climatic, ultraviolet radiation, and oceanographic changes leading to impacts on population demography and changes in the number and distribution of species.

Fautin *et al*. (2010) reviewed factors that influence marine biodiversity in the United States, which are largely similar to those affecting ecosystems in the North Pacific Ocean. These included over-exploitation, degradation of water quality, invasive species, rising sea temperatures, increasing surface concentrations of CO_2, shifting currents, and an increasing number and size of hypoxic or anoxic areas. Coastal development and shipping were identified as activities associated with consequences for biodiversity. However, the direct and indirect effects of fishing were identified as the greatest threat to marine biodiversity. Specifically, fishing-related impacts included severe depletions of upper-trophic level predators and cascading food web interactions, selective removals, and alteration of the structure of benthic communities.

Parsons *et al*. (2014) reviewed the major threats to biodiversity, including exploitation, marine pollution, climate change, and the introduction of non-indigenous species. Collectively, fisheries are exerting major changes to biodiversity in the North Pacific Ocean. Of the commercially fished species that have been assessed, at least 87% are fully exploited, over-exploited or depleted (FAO, 2012; Parsons *et al*., 2014). As the global distribution of fishing effort increases in terms of spatial extent and depth (Morato *et al*., 2006; Swartz *et al*., 2010, as in Parsons *et al*., 2014), so too does the biodiversity affected by fishing. As the global human population size increases, so do the impacts of coastal development and input of environmental pollutants to the world's oceans (Islam and Tanaka, 2004, as in Parsons *et al*., 2014). This concentration of human activities in coastal ecosystems has led to increases in pollutant discharges into marine ecosystems, ingestion of inorganic contaminants by marine biota (*e.g*., Avery-Gomm *et al*., 2012, as in Parsons *et al*., 2014), introduction of persistent organic pollutants (Braune *et al*., 2005, as in Parsons *et al*., 2014), spread of non-indigenous species (Bax *et al*., 2003, as in Parsons *et al*., 2014), and oil spills (Hjorth and Nielsen, 2011, as in Parsons *et al*., 2014). The impacts of overfishing, coastal development, marine pollution, and spread of non-indigenous species on the distributions of biota are further compounded by a changing ocean environment that is predicted to warm and acidify with higher sea level, and changes in ocean circulation and storm regimes (IPCC 2013, as in Parsons *et al*., 2014).

Research priorities

PICES was conceived as a means of avoiding the duplication of scientific activities, and in 1992, Governing Council underscored "a role of PICES with respect to other organizations would be to supply advice through Science Board and relevant scientific committees." Thus, in addition to identifying key drivers of biodiversity change, members of SG-BC identified priorities for biodiversity research and the types of advice that are needed to inform ecosystem-based management in the North Pacific Ocean. These include:

- Identifying indicators or proxies for marine biodiversity in different ecosystems;
- Identifying reference points for biodiversity indicators for different marine ecosystems;
- Developing a monitoring strategy to assess the current state of biodiversity and monitor long-term trends in distribution and abundance;
- Identifying areas that differ in the rates of biodiversity change, and potential drivers causing these changes;
- Delineating benthic and pelagic biogeographic ecoregions in the North Pacific;
- Understanding the factors that contribute to local biodiversity (*e.g*., for specific biomes or habitat types) and their susceptibility to particular anthropogenic impacts;
- Predicting impacts of climate change and other drivers on species distribution and biodiversity patterns;
- Mapping biodiversity hotspot testing for correspondence with hotspots of stressors/ pressures;
- Understanding the cumulative impacts of drivers of biodiversity change;
- Identifying VMEs, including deepwater biogenic habitats that are impacted by bottom-contact fishing gear;
- Identifying EBSAs in the deep sea and open ocean in support of the Convention on Biological Diversity, and specifying commonalities with regional VMEs, the International Seabed Authority's Areas of Particular Environmental Interest and the International Maritime Organization's Particularly Sensitive Sea Areas;
- Developing effective tools for MPA network design and marine zoning;
- Developing effective means of controlling and managing ballast water (*e.g*., inspection systems), particularly near international harbours;
- Understanding the vectors of non-indigenous species transport.

SG-BC also noted that the identification of biodiversity indicators and reference points is needed for assessing the status of biodiversity in different marine ecosystems and informing ecosystem-based management decisions. Delineation of biogeographic ecoregions is a first step in the identification of regional biodiversity patterns that can help assess how current and proposed management measures (*e.g*., MPAs or spatial gear restrictions) are expected to affect regional biodiversity and serve as an input in marine zoning and MPA network design. Identification of VMEs is needed to advise the NPFC and prevent serious adverse impacts to VMEs.

3 Potential Mechanisms to Advance Biodiversity-based Scientific Research in the North Pacific Ocean

In its initial review, SG-BC identified a range of mechanisms to advance biodiversity-based research in the North Pacific Ocean. These include mechanisms related to the coordination of information management, analyses, and resources such as:

- Construction of regional databases of VME indicator species, and biogenic species that support local biodiversity;
- Development of monitoring programs and rapid response plans to detect and manage changes in biodiversity and the distribution of non-indigenous species;
- Development of risk assessment tools;
- Identification of pathways of effects (*e.g.*, vectors of non-indigenous species introductions);
- Development of species distribution models for indicator species (*e.g.*, VME indicators) and biodiversity indices;
- Development and evaluation of options for encounter protocols to prevent serious adverse impacts to VMEs;
- Development of genetic tools to quantify population connectivity for key taxa at the North Pacific basin scale;
- Identification of planned biodiversity research expeditions that may benefit from international participation or information dissemination.

The United States noted that there is no formal mechanism for implementing monitoring, collating existing data or maintaining ongoing data on biodiversity in its domestic waters. There is also a lack of uniform biodiversity measures that can be compared among ecosystems in the North Pacific region. These are challenges for recognizing changes in biodiversity in a timely manner when they may occur.

The United States identified two additional mechanisms to advance biodiversity research:

1. Networking pilot projects across the North Pacific Ocean;
2. Planning biodiversity research expeditions that may benefit from international participation or information dissemination.

Specific tools for advancing biodiversity research included:

- Databases of biogenic habitat-forming species that contribute to local biodiversity (*e.g.*, deep-sea corals and sponges);
- Habitat suitability models for deep-sea corals and sponges;
- Genetic tools to identify population connectivity for these and other key taxa at the North Pacific basin scale;
- Models and predictive maps of the spatial distribution of biodiversity;
- Ecosystem models that can predict the effects of human activities or climate change on biodiversity (*i.e.*, EcoPath, EcoSim models);
- Monitoring programs to detect changes in biodiversity.

Rapid and open access to spatially and temporally referenced data is recognized as essential for recognizing changes as they occur and informing timely management decisions (Hall *et al*., 2010, as cited in CCA, 2012). Fautin *et al*. (2010) noted the importance of developing data management techniques to ensure that scales and survey methods are compatible, that taxonomic changes are updated automatically, and that biotic and abiotic data are interactively linked. Key changes for managing data effectively include financial constraints and limited taxonomic expertise.

4 Review of Research Activities Undertaken by PICES and Other International Organizations on Biodiversity in the North Pacific Ocean

Keyword searches of "biodiversity" and "conservation" in PICES' Annual Reports indicate that PICES' interests in biodiversity research and conservation have steadily increased since its establishment in 1992. The review also showed that a number of PICES expert groups have incorporated biodiversity-related research objectives into their Actions Plans. The number of proposed and accepted topic sessions related to biodiversity or conservation at PICES Annual Meetings has also increased over time. However, PICES has published relatively few reports that specifically address biodiversity research or conservation issues (but see Alexander *et al*., 2001; Jamieson and Zhang, 2005; Jamieson *et al*., 2010).

4.1 Biodiversity research published by PICES expert groups

Most of the biodiversity research published by PICES expert groups relates to identification of biodiversity indicators and the Census of Marine Life (CoML). Note this review does not include an exhaustive search of primary papers produced by members of PICES expert groups.

In the reports of the Study Group on *Ecosystem-Based Management Science and its Application to the North Pacific* and the Working Group on *Ecosystem-Based Management Science and its Application to the North Pacific* (WG 19), biodiversity conservation was identified as a key objective for ecosystem-based management (Jamieson and Zhang, 2005; Jamieson *et al*., 2010). Specifically, WG 19 provided a detailed analysis of indicators for use in supporting ecosystem monitoring and management, including biodiversity indicators. PICES also published a Scientific Report on integration of ecological indicators (No. 33, Kruse *et al*., 2006) based on the PICES/NPRB Workshop on "*Integration of ecological indicators of the North Pacific with emphasis on the Bering Sea*".

The Proceedings of the PICES/CoML/IPRC Workshop on "*Impact of Climate Variability on Observation and Prediction of Ecosystem and Biodiversity Changes in the North Pacific*" (PICES Sci. Rep. No. 18, Alexander *et al*., 2001) provided an overview of initiatives and strategies for monitoring, understanding and predicting changes in biodiversity in the North Pacific Ocean.

4.2 Biodiversity-related research or activities led by PICES Committees and expert groups

PICES Committees and expert groups that have undertaken research specifically focused on biodiversity or conservation include the Marine Environmental Quality (MEQ), Fishery Science (FIS) and Biological Oceanography (BIO) committees, Working Groups (WG 19, *Ecosystem-based Management Science and its Application to the North Pacific*; WG 21, *Non-indigenous Aquatic Species*; WG 28, *Development of Ecosystem Indicators to Characterize Ecosystem Responses to Multiple Stressors*) and the Advisory Panel on *Marine Birds and Mammals*. PICES' scientific program, FUTURE, also addresses biodiversity issues. Most PICES activities related to biodiversity and conservation have been undertaken in the last 10–15 years, and highlights are summarized below.

MEQ identified biodiversity, species introductions and unintentional introductions of exotic species as ecological health issues in its draft 2006 Action Plan. Other issues considered in the Action Plan were anthropogenic impacts on benthic habitat (formerly described in the Plan as "trawling effects on benthic habitat") and anthropogenic impacts on trophic dynamics and biodiversity that impact system sustainability. In 2003, MEQ, BIO and FIS convened a Topic Session (S10) on "*Ecosystem-based* *management science and its application to the North Pacific*" (PICES XII).

Starting at the 2004 PICES Annual Meeting, MEQ has convened or co-convened:

- MEQ Topic Session (S6) on "*Marine Protected Areas*" (PICES XIII, 2004);
- MEQ Workshop (W2) on "*Introduced species in the North Pacific*", co-sponsored by ICES (PICES XIV, 2005).

Together, MEQ and FIS have organized several topic sessions or workshops related to biodiversity conservation and emerging scientific questions surrounding the identification of VMEs and EBSAs. These include:

- MEQ/FIS Workshop (W3) on "*Criteria relevant to the determination of unit eco-regions for ecosystem-based management in the PICES area*" (PICES XV, 2006);
- MEQ/FIS Topic Session (S7) on "*Coldwater biogenic habitat in the North Pacific*" (PICES XVI, 2007);
- MEQ/FIS Topic Session (S6) on "*Marine spatial planning in support of integrated management tools, methods, and approaches*", co-sponsored by NOWPAP (PICES-2009);
- MEQ/FIS Topic Session (S11) on "*Identifying vulnerable marine ecosystems in the North Pacific*", co-sponsored by NPFMC (PICES-2010).

BIO has convened:

- BIO Topic Session (S4) on "*Census of Marine Life – Exploring ocean life: Past, present and future*" (PICES- 2010);
- BIO/POC Topic Session (S2) on "*Mechanisms of physical-biological coupling forcing biological hotspots*" (PICES-2011).

WG 19 has produced two reports that identify biodiversity conservation as a key objective for ecosystem-based management, and review biodiversity indicators appropriate for monitoring and managing ecosystems (Jamieson and Zhang 2005; Jamieson *et al*., 2010).

Working Group (WG 21) on *Non-indigenous Aquatic Species* met for a 2-day joint meeting on Non-indigenous Aquatic Species with ICES Working Group on Introductions and Transfers of Marine Organisms (WGITMO) and with ICES/IOC/IMO Working Group on Ballast and other Ship Vectors (WGBOSBV) in Cambridge, USA (May 2007). The Study Group on *Future Integrative Scientific Program(s)* (SG-FISP, 2005–2009) identified biodiversity, species introductions and unintentional introductions of exotic species as one of six themes for a new PICES scientific program prior to PICES XIV. The recommendations from SG-FISP led to the establishment of PICES' integrative scientific program FUTURE (**F**orecasting and **U**nderstanding **T**rends, **U**ncertainty and **R**esponses of North Pacific **E**cosystems).

PICES has co-convened workshops with other organizations including:

- A 3-day PICES/CoML/IPRC Workshop on "*Impact of climate variability on observation and prediction of ecosystem and biodiversity changes in the North Pacific*", March 7–9, 2001, Honolulu, USA (see Appendix 4);
- A 1-day PICES/CKJORC Workshop (W5) on "*Regional cooperation for the conservation and management of the marine environment and resources in the Yellow Sea*" (PICES XI, 2002);
- A ½-day KORDI/PICES/CoML workshop on "*Variability and status of the Yellow Sea and East China Sea ecosystems*", October 3, 2003, Seoul, Korea (see Appendix 4);
- A 3-day PICES/CoML *Regional marine life expert* workshop, November 17–19, 2003, Victoria, Canada;

Representatives from PICES have also participated in workshops held by other organizations, including a workshop on Ecologically and Biologically Significant Areas, convened by the Convention on Biological Diversity Secretariat in Moscow, Russia (February 2013), and a workshop on "*Marine biodiversity conservation and marine protected areas in the Northwest Pacific*", convened by NOWPAP in Toyama, Japan (March 2013) (see Appendix 4).

A theme section in the journal *Marine Ecological Progress Series* Volume 487 on biophysical coupling of marine hotspots was based on PICES Topic Session S2 at PICES-2011 (Hazen *et al*., 2013a).

Most recently, PICES has contributed to the World Ocean Assessment Chapter 36C[19] on the status of marine biological diversity and habitats in the North Pacific Ocean.

[19] http://www.un.org/depts/los/global_reporting/WOA_RegProcess.htm

4.3 Activities undertaken by international organizations

Adrianov (2004) provides a review of activities undertaken by international organizations in the western and northern Pacific Ocean.

- DIVERSITAS[20] was launched to study and monitor biodiversity and ecosystem function;
- The Intergovernmental Oceanographic Commission of UNESCO developed a Register of Marine Organisms,[21] a checklist of all marine species;
- DIWPA[22] (DIVERSITAS in Western Pacific and Asia) was established to promote cooperative studies on biodiversity and ecosystems;
- DIWPA developed a regional strategy for studying ecosystems from the subarctic areas to New Zealand, and established 21 coastal areas for long-term annual monitoring; seven are in the western Pacific Ocean;
- The Census of Marine Life[23] (CoML) was established to explain biological diversity and distribution in the world's oceans;
- NaGISA[24] (Natural Geography in Shore Areas) aimed to assess and study marine biodiversity in macrophyte coastal communities of the West and North Pacific Ocean.

A number of international organizations have engaged in scientific activities related to biodiversity conservation in the North Pacific Ocean. The Global Ocean Biodiversity Initiative (GOBI)[25] is an international organization working to define EBSAs in the world's oceans (Williams *et al*., 2010, as in Hazen *et al*., 2013a). The workshop on Ecologically and Biologically Significant Areas held in 2013 in Moscow (see above) evaluated EBSAs in the North Pacific Ocean. Key EBSAs identified during that workshop included those in the domestic waters of Mexico and Russia, as well as the Emperor Seamount Chain, seamounts and hydrothermal vents in the Northeast Pacific Ocean, and the transition zone. However, most of the areas in the high seas, including the majority of seamounts and the abyssal plain were not evaluated.

Related to EBSAs are vulnerable marine ecosystems. The NPFC[26] Scientific Working Group has as one of its priorities to identify VMEs in the convention area. NPFC held a joint workshop on VME identification with FAO in Tokyo, Japan, in March 2014 and a workshop on VME identification and encounter protocols in Tokyo, Japan, in August 2014. The criteria for VME identification have yet to be defined and applied in the convention area.

Other international organizations undertaking biodiversity research in the North Pacific Ocean include the International Network for Scientific Investigation of Deep-Sea Ecosystems (INDEEP),[27] Integrated Marine Biogeochemistry and Ecosystem Research (IMBER,[28] effects of ocean acidification), NOWPAP,[29] WESTPAC,[30] IPBES,[31] CoML, and DIVERSITAS.

[20] https://www.icsu.org/about-us/a-brief-history
[21] http://www.marinespecies.org/urmo/
[22] http://diwpa.ecology.kyoto-u.ac.jp/body.html
[23] http://www.coml.org/about-census
[24] http://www.coml.org/projects/natural-geography-shore-areas-nagisa
[25] http://www.gobi.org/
[26] http://npfc.r-cms.jp/
[27] http://www.indeep-project.org/
[28] http://www.imber.info/
[29] http://www.nowpap.org/
[30] http://iocwestpac.org/
[31] http://www.ipbes.net/

5 Potential Opportunities for Collaborations between PICES and Other International Organizations

SG-BC recognized that countries and international organizations have developed action plans and have carried out biodiversity research at global, regional and national levels in recent years, including the Convention on Biological Diversity, International Biodiversity Program, Millennium Ecosystem Assessment, and Census of Marine Life. SG members identified potential opportunities for collaboration with other organizations to undertake or support biodiversity research in the North Pacific Ocean. Key opportunities include:

- Collaboration with the North Pacific Fisheries Commission (NPFC) to identify the location of VMEs in the convention area. In its 2008 annual report, MEQ proposed that PICES has the scientific expertise and capacity to evaluate the appropriateness of criteria relevant to the determination of VMEs in the North Pacific and to evaluate the adequacy of the information available to apply the criteria. NPFC identified PICES as a potential partner for VME identification and other scientific priorities at its Scientific Working Group Meeting held in Juneau, USA, in 2012. More recently, the NPFC Interim Secretariat supported the idea of developing a formal collaboration with PICES. In addition, ongoing work conducted in the South Pacific Regional Fishery Management Organization (SPREFMO) region may have direct applicability for similar PICES work in the North Pacific;
- Collaboration with the CBD Secretariat to identify EBSAs in the North Pacific Ocean, with an emphasis on evaluating areas not yet assessed;
- Collaboration with NOWPAP on biodiversity research, including topics related to non-indigenous marine species. NOWPAP is one of the UNEP Regional Seas Programs. During its term, WG 21 recognized the benefits of cooperation on marine non-indigenous species between PICES and NOWPAP. NOWPAP's 2012–2017 Strategy includes sharing information on the current status of biodiversity, including marine invasive species, and an application of international regulations for the prevention of alien species invasions. A joint PICES-NOWPAP Study Group on *Scientific Cooperation in the North Pacific Ocean* was formed in July 2014 (SG-SCOOP);
- Collaboration with ICES to understand drivers/ responses of Northern Hemisphere marine ecosystems to changes in biodiversity;
- If a biodiversity expert group is established within PICES, it could develop a formal collaboration and affiliation with DIVERSITAS.

The United States has significant capacity for marine biodiversity research in the academic and government sectors, and a large number of initiatives that touch on providing information needed to advance the conservation of ocean biodiversity in the North Pacific Ocean. Most of these are directed toward specific geographies within U.S. waters, or to specific research questions. Listed here are initiatives that would benefit from collaboration or linkages with other PICES members.

- Marine Biodiversity Observation Network (MBON; Duffy *et al*., 2013). In October 2014, a consortium of U.S. agencies announced three pilot projects, two of which have sentinel sites along the California coast;
- National Science Foundation;
- Smithsonian Institution – National Museum of Natural History. The Smithsonian Institution was a principal player in the Census of Marine Life efforts, and its Tennenbaum Marine Observatories are a new effort to develop a worldwide network of coastal ecological field sites, standardizing measurements of biological change;

- National Oceanic and Atmospheric Administration (NOAA):
  - Deep Sea Coral Research & Technology Program (Field Research Initiatives in the Northeast Pacific, 2010–2014; U.S. Pacific Islands, 2015–2017), and National Deep-Sea Coral and Sponge Database;
  - Ocean Exploration and Research – Various exploration expeditions in the North Pacific, including planned ROV expeditions in 2015–2017;
  - Coral Reef Conservation Program – Coral Reef Biodiversity Monitoring and participation in the Census of Marine Life's Census of Coral Reefs Ecosystems;
  - Ocean Acidification Program – An important area of focus includes studying the biological responses of marine species to changing ocean chemistry. The Program is coordinating internationally to develop a global Ocean Acidification Observing Network (Newton *et al*., 2012).
  - National Marine Sanctuary Program and Pacific Island Marine National Monuments – These programs have the conservation of biodiversity as a primary mandate.

The U.S. also participates in a number of international activities related to marine biodiversity including:

- The Ocean Biogeographic Information System (OBIS), a global network of regional and thematic (taxon-based) data nodes that is organized within the Intergovernmental Oceanographic Data and Information Exchange within UNESCO's International Oceanographic Commission (IOC). The U.S. node, OBIS-USA, has been a leader in the OBIS activity since it was first proposed for adoption by the IOC. OBIS has been involved in global efforts to capture scientific data for use in international fora. As an example, OBIS has been a major contributor to CBD EBSA efforts. Duke University (OBIS SEAMAP) has led several regional workshops on this topic. PICES participant countries with OBIS nodes include Canada, China, Korea, Japan, and the U.S.;
- Global Ocean Observing System (GOOS);
- Group on Earth Observations Biodiversity Observation Network (GEO BON).

Furthermore, Ban *et al*. (2014) identified several international organizations that could potentially partner with PICES to address biodiversity-related research questions:

- International Maritime Organization (IMO),[32] which is responsible for safe and secure shipping and the prevention of marine pollution by ships;
- International Seabed Authority (ISA),[33] which controls exploration and exploitation of nonliving resources;
- Intergovernmental Oceanographic Commission (IOC),[34] which leads international oceanographic research;
- United Nations Environment Program (UNEP),[35] which coordinates activities and programs for conservation and sustainable use of oceans, including the Regional Seas Conventions and Action Plan.

[32] http://www.imo.org/en/Pages/Default.aspx
[33] https://www.isa.org.jm/
[34] http://www.ioc-unesco.org/
[35] http://web.unep.org/

6 Conclusions and Recommendations

6.1 Merits of establishing an expert group focused on biodiversity science

SG-BC expressed support for PICES to establish an expert group on biodiversity and to engage in biodiversity science. The SG recognized it was an opportunity for PICES to link research to the activities and initiatives of other international organizations, including the North Pacific Fisheries Commission.

SG-BC's review of PICES past activities reveals that biodiversity science was recognized as a significant emerging issue by PICES as early as 2000 (see individual reports in the PICES Annual Report for 2000). The Study Group on *Future Integrative Scientific Program(s)* identified the status and trends of marine biodiversity as an important theme for PICES in 2005 and in 2006, and FIS agreed that biodiversity was a topic of much interest to PICES member countries. Biodiversity and productivity of marine organisms was identified as one of six new frontiers at the PICES/ICES Early Career Scientists Conference on "*New frontiers in marine science*" in 2007. In 2011, marine spatial planning was identified as one of four long-term research priority areas for PICES and ICES cooperation by the joint PICES/ICES Study Group on *Developing a Framework for Scientific Cooperation in Northern Hemisphere Marine Science*.

In 2013, WG 21 proposed, as an option for an expert group, to establish a Section on conservation focused on drivers of change in biodiversity to address emerging international issues, including work advocated by NOWPAP and the Convention on Biological Diversity (CBD), to collaborate with the North Pacific Fisheries Commission (NPFC) on identification of VMEs, and to study the effects of non-indigenous species on marine biodiversity. WG 21 ultimately favoured the option to establish an Advisory Panel on *Aquatic Non-indigenous Species* in its final report.

SG-BC identified climate change, pollution, fishing, coastal development, and the spread of non-indigenous species as the key anthropogenic drivers of biodiversity change in the North Pacific Ocean. The SG also recognized that ecological interactions influence biodiversity patterns. When cross-referenced against past and present PICES activities (see Table 1 in section 1), all drivers of biodiversity change were the subject of research by PICES member countries, with the exception of fishing. However, SG-BC noted that these research activities were not necessarily focused on biodiversity *per se*.

SG-BC then developed a list of list of biodiversity research themes that could be addressed by PICES. Five themes were identified:
- Baseline inventories of biodiversity;
- Understanding and predicting spatial distributions of biodiversity;
- Understanding temporal variation in biodiversity;
- Assessing vulnerability;
- Analytical tools for biodiversity conservation.

When cross-referenced against a list of past and present PICES activities, it was apparent that relatively few PICES expert groups have focused research on biodiversity in the North Pacific (Table 2, section 1). Given the results of this gap analysis, SG-BC concluded that establishing a new expert group to focus on biodiversity research would complement existing PICES activities and address key research priorities shared by member countries.

6.2 Biodiversity research activities that an expert group might undertake

During initial correspondence, SG-BC members differed in their perspectives on whether an expert group would fulfill a narrow specialized role, or serve as an umbrella for a broad diversity of biodiversity issues. For instance, some SG-BC members discussed the potential for an expert group to model itself after ICES' Strategic Initiative on Biodiversity Advice and Science (SIBAS)[36] which has a key focus on aquatic invasive species, but also deals with EBSAs and MPAs.

Alternatively, an expert group focused on biodiversity science within PICES could play a similar role to ICES' long-standing Working Group on Deep-water Ecology (WGDEC) which has played a valuable role in providing scientific advice to the Northeast Atlantic Fishery Commission (NEAFC), Northwest Atlantic Fishery Organization (NAFO) and the OSPAR Commission. It has filled a niche on science issues related to the high seas. *Inter alia*, ICES' WGDEC has provided useful analyses and approaches to identifying VMEs in the region.

SG-BC recommended that an expert group focused on biodiversity research should initially focus on a well-defined and narrow scope, and select from one or more research themes identified by SG-BC member countries as priorities (Table 2, *ibid*). To evaluate the proposed research themes, a list of criteria was devised that:

- Supports research that focuses on one or more drivers of biodiversity change;
- Addresses common knowledge gaps identified in the review;
- Provides clear linkages to PICES expert groups;
- Provides a new research direction in PICES;
- Is narrowly focused;
- Has the potential to develop into a primary publication;
- Is achievable;
- Has clear applications.

Three ideas were proposed by SG-BC and evaluated against these criteria (Table 3, *ibid*):

- Develop a plankton/nekton biodiversity network;
- Develop technical guidance on how to monitor biodiversity;
- Study the diversity and distribution of biogenic habitat.

The first proposal was evaluated positively but identified as research that could potentially duplicate past or present PICES activities, while the second was considered to have strong management applications but was of lesser scientific interest. The third option, researching the diversity and distribution of biogenic habitats, was favourably reviewed against all evaluation criteria. The results of SG-BC's gap analysis and its proposed topic for a new expert group was presented to MEQ, FIS and BIO at PICES-2014 and the proposed topic was generally supported by all three Committees. BIO was identified as the most appropriate parent.

6.3 Recommendations for a Working Group

Based on its reviews of research priorities, and past and present PICES activities, SG-BC recommends the establishment of a Working Group on *Biodiversity and Biogenic Habitats*, with an initial focus on coral- and sponge-dominated ecosystems. The proposed Working Group will advance understanding of the distribution of coral and sponge taxa in the North Pacific Ocean and their contribution to biogenic habitats and biodiversity. This effort represents a new emphasis on habitat research for PICES, and the initial focus on biogenic habitat could provide a proof of concept on how to undertake biodiversity research related to other taxa/ecosystems. Major applications of the science products developed by the Working Group would be the provision of technical guidance on the development and application of species distribution models, maps of known and predicted distributions of biogenic habitats, and the development of biodiversity indicators.

Context

In 2014, PICES convened a 1-year Study Group on *Biodiversity Conservation* (SG-BC). PICES had no formal mechanism to exchange information on issues related to biodiversity in the North Pacific despite recent requests to do so, for example, from the Convention on Biological Diversity in 2013. Marine biodiversity is important for maintaining ecosystem structure and function which, in turn, supports numerous ecosystem goods and services, including sustainable fisheries.

The terms of reference for SG-BC included an assessment of the merits of establishing an expert group focused on biodiversity science within PICES, and providing recommendations on the role of such a group. Through inter-sessional work and its business meeting at PICES-2014 (October 18, 2014, Yeosu, Korea), attended by members from Canada, Korea, and the U.S., and with written submissions from

[36] http://ices.dk/community/groups/Pages/SIBAS.aspx

China and Japan to guide discussions, SG-BC identified several opportunities for further collaboration on marine biodiversity. Cooperation on advancing the understanding of corals and sponges as biogenic habitat in the North Pacific was deemed particularly timely and appropriate for the work of a new PICES Working Group.

Many corals and sponges are known to form fragile biogenic habitats. These three-dimensional features provide habitat for numerous fish and invertebrate species. They are associated with greater abundance of some commercially-targeted species and appear to enhance the local biological diversity of many ecosystems. Corals and sponges are also strongly influenced by biological and physical oceanographic processes, and their distribution and biodiversity are anticipated to respond to multiple stressors, including climate change, pollution, aragonite saturation, and fishing. Conservation of these biogenic habitats has been identified as a priority in a number of countries and international fora. Analyses of the spatial distribution and diversity of these taxa and associated fauna in the North Pacific have lagged significantly behind studies in the North Atlantic.

The merits of this focus include:

- A new research avenue for PICES with clear linkages to PICES activities, particularly BIO and WG 28;
- An opportunity to initially concentrate on biogenic habitat that can serve as a model for future biodiversity research on other taxa/ ecosystems and address a lack of knowledge of benthic habitats in deeper waters;
- New data from at least five PICES member countries (Canada, China, Japan, Korea and U.S.) that could be integrated to better understand factors that influence distribution and trends in biogenic habitat diversity, and test key scientific questions of broad interest (*e.g.*, model transferability);
- A gathering of knowledge, assessing current status, developing indicators to monitor change, and hypotheses to forecast responses to multiple stressors to align with the spirit of FUTURE. Moreover, the key outputs of this Working Group (distribution maps, biodiversity indicators) would likely be of broad interest outside of PICES;
- Addressing a targeted ecological question that can lead to scientific products within 3 years.

Terms of reference

Year1:

- Compile data on the distribution of coral and sponge taxa, and associated fish and invertebrate assemblages in the North Pacific within National Exclusive Economic Zones (EEZs) and facilitate their submission to appropriate biodiversity databases (*e.g.*, Ocean Biogeographic Information System (OBIS));
- Compile data on key variables (temperature, velocity, ocean acidification, slope, aspect) hypothesized to influence coral and sponge distribution and diversity and catalogue sources of multibeam/swathe bathymetry data for distribution modeling within National EEZs;
- Hold a WG meeting, in conjunction with the PICES Annual Meeting.

Year 2:

- Review modeling approaches to predict the potential distributions of species and habitat suitability for corals and sponges (*e.g.*, MaxEnt, Boosted Regression Trees, or high resolution bathymetry-based models) within National EEZs;
- Identify environmental and ecological predictors of patterns in the distribution and biodiversity of coral, sponge and associated taxa within National EEZs;
- Convene a session on biogenic habitat distribution and diversity at the PICES Annual Meeting;
- Hold a WG meeting, in conjunction with the PICES Annual Meeting.

Year 3:

- Review and propose potential indicators for assessing and monitoring diversity of biogenic habitats;
- Review and document associations between commercially important fish and invertebrate species and biogenic habitats;
- Prepare scientific reports for dissemination of results;
- Hold a WG meeting, in association with the PICES Annual Meeting.

Key scientific outputs

- Technical guidance on development and application of predictive species and habitat modeling approaches for deep-sea corals and sponges;
- Maps of known and predicted distribution and abundance of biogenic habitat (and diversity) in the North Pacific Ocean;
- Biodiversity indicators for biogenic habitat assessment and monitoring.

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Appendix 1

SG-BC Terms of Reference

1. Review the scope of key drivers of biodiversity change in the North Pacific Ocean, including, but not limited to: non-indigenous marine species, climate change, fishing, and eutrophication.
2. Identify potential mechanisms to advance biodiversity-based scientific research and/or conservation related to drivers of biodiversity change in the North Pacific Ocean.
3. Review the research activities, past and present, undertaken by PICES and other international organizations on biodiversity in the North Pacific Ocean.
4. Identify opportunities for collaboration, new research opportunities for PICES, and the potential to provide science-based advice that could be used to inform decisions related to the conservation and management of biodiversity in the North Pacific Ocean.
5. Prepare a final report that includes an assessment of the merits of establishing an expert group focused on biodiversity science within PICES, and provide recommendations on the role(s) of such a group.

Appendix 2

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Appendix 3

Meeting Reports from Past Annual Meetings

PICES Twenty-second Annual Meeting (PICES-2013)
October 11–20, 2013
Nanaimo, Canada

Extracted from:

Report of WG 21 on *Non-indigenous Aquatic Species*

WG 21 Endnote 3

Recommendations for future PICES activities on NIS

WG 21 makes the recommendations to Science Board on the following [two] options for continuing activities related to marine nonindigenous species:

Option 1 – Create a section focused entirely on marine non-indigenous species

Terms of reference

1. Continue to share information and taxonomic expertise and update the database and atlas on new introductions to ecoregions;
2. Evaluate how changes in patterns of trade affect pathways and vectors, and provide new species pools from donor regions (*e.g*., in the potential opening of a north polar sea route, it is possible that NIS could spread between the North Atlantic and North Pacific);
3. Develop a protocol for sampling non-indigenous aquatic species in PICES member countries, including a method for sampling on polar sea route ships;
4. Develop a better understanding of changing distributions of NIS and vectors in the context of global climate change and its impacts on temperature, salinity, ocean acidification and deoxygenation;
5. Develop capacity for predicting changes in the distribution patterns of selected marine NIS among PICES member country ports over the next 100 years as global climate change leads to the opening of new pathways (*e.g*., shipping in the Arctic);
6. Evaluate the risk of biofouling (hull fouling and tsunami debris) as a vector for the introduction of NIS. Additionally, evaluate the individual risks presented by species commonly encountered in biofouling vectors;
7. Investigate why some species establish over broad areas while some only establish restricted distributions. Compare widely distributed species (*e.g*., green crab) with those of the same phyla with a narrow distribution. This information could be used in future risk assessments;
8. Changing vectors (*e.g*., biofouling ships + tsunami debris (a novel vector) and understanding the risk of these species);
9. Plan workshops/special sessions, for example:
   - Support a joint PICES/ICES Theme Session on "*The increasing importance of biofouling for marine invasions: an ecosystem altering mechanism*" at the 2014 ICES Annual Science Conference in Spain;
   - Propose a workshop/session on mitigation and control measures to reduce the impacts on NIS on the marine environment;
   - Propose a workshop session on the role of global climate change in species' range expansion and human-mediated introductions.
10. Work with NOWPAP and ICES to accomplish the terms of reference;
11. Work with other PICES expert groups to accomplish the terms of reference;
12. Prepare a final report on accomplishments.

Option 2 – Create a Section on Conservation Focused on Drivers of Change in Biodiversity

Terms of Reference

Partnerships:
- Establish linkages with other intergovernmental organizations dealing with biodiversity issues (*e.g*., ICES, NOWPAP, WESTPAC, NPFC, CBD, FAO)
- Document and predict patterns in biodiversity:
  - Identify potential mechanisms to store and share information/data on biodiversity issues in the North Pacific (and beyond), *e.g*., PICES atlas on NIS, NPFC SWG to build and update databases of the past and current distributions of key commercial and non-commercial species, including database of NIS, at the scale of ecoregions.
  - Identify areas that support high, rare, or unique biodiversity, including VMEs and EBSAs in collaboration with international organizations including CBD, FAO, NPFC, NOWPAP using international criteria (*e.g*., CBD criteria for EBSA identification; FAO criteria for VME identification).

Understanding drivers of change in biodiversity:
- Identify major drivers of change in biodiversity in the North Pacific Ocean, including non-indigenous marine species, climate change, fishing, and eutrophication, and develop pathways of effects models for related activities that describe the mechanisms of change, including interactions among multiple stressors.
- Develop indicators to assess how drivers and biodiversity are changing over time and space (*e.g*., ecosystem status index).
- Develop models that relate changes in environmental (*e.g*., climate-related changes in temperature, salinity, pH and O_2, human (*e.g*., changes in the distribution of fishing effort, discharge of effluents), and ecological variables (*e.g*., change in community structure) to changes in species distribution patterns, including changes in NIS distributions.
- Develop models and predictions of change in biodiversity under alternative scenarios of climate change, NIS introductions, fishing patterns, eutrophication, or other key threats.
- Investigate impacts of NIS, fishing, climate change, contaminants (and other key threats) in areas that support high, rare, unique or endangered biodiversity.
- Identify how human societies around the North Pacific value marine biodiversity and how they benefit from naturally diverse marine ecosystems.

Provision of science advice:
- Develop risk assessments for areas that support high, rare, unique or endangered biodiversity.
- Review mechanisms to conserve biodiversity in the North Pacific, including development/implementation of Ecologically and Biologically Significant Areas (EBSAs), identification of Vulnerable Marine Ecosystems (VMEs), Marine Protected Areas (MPAs), *etc*. and identify mechanisms to preserve endangered and threatened species in the North Pacific.
- Respond to emerging issues related to biodiversity.
- Prepare science advisory reports on key biodiversity issues.
- Work with other PICES expert groups to accomplish the Terms of Reference.
- Prepare a final report on accomplishments.

PICES Twenty-third Annual Meeting (PICES-2014)
October 17–26, 2014
Yeosu, Korea

Report of the Study Group on *Biodiversity Conservation*

The Study Group on *Biodiversity Conservation* (SG-BC) met from 9:00 to 18:00 on October 18, 2014, at PICES-2014 in Yeosu, Korea, to review progress on its activities, prepare a set of recommendations for a new expert group, and prepare information for its final SG report. SG-BC Chair, Dr. Janelle Curtis, welcomed participants to the meeting, and introductions were made (*SG-BC Endnote 1*).

Dr. Curtis began the meeting with a review (*SG-BC Endnote 2*) of SG-BC activities and progress to date, a review of PICES past and present activities related to biodiversity conservation, and member country perspectives on the key drivers of biodiversity change and important knowledge gaps that PICES could address. The SG spent the afternoon reviewing the list of drivers of biodiversity change, identifying key research questions that could be addressed by a new PICES expert group, and drafted a set of recommendations on the roles that such a group would fulfill.

AGENDA ITEM 2
SG-BC activities and progress

Significant progress has been made on all SG-BC terms of reference, and the SG anticipates a final report will be submitted to Science Board in January 2015.

1. Review drivers of biodiversity change: draft review complete

All SG-BC members drafted summaries of key drivers which were reviewed and summarized in the SG draft final report. Key drivers were grouped into six themes: climate change, fishing, pollution, non-indigenous species, coastal development, and ecological factors. SG-BC members also noted the importance of interactions among multiple drivers (*SG-BC Endnote 3*, Table 1). The countries where these drivers are important were also identified. The driver themes were then cross-referenced with the topics of past and present PICES expert groups. While PICES has engaged in relatively little research related to biodiversity, of particular note is the lack of PICES expert group focused on the influences of fishing or ecological interactions on the spatial and temporal patterns of biodiversity.

2. Identify mechanisms for advancing biodiversity-based research: in progress

SG-BC members submitted ideas for mechanisms to advance biodiversity research in the North Pacific Ocean, as reviewed in the SG draft report. The report will be updated to reflect additional suggestions made during the SG-BC meeting, including the development of a basin-wide network of observation and monitoring sites, and support of new or existing databases for compiling biodiversity data.

3. Review biodiversity activities of PICES and other organizations, and 4. Opportunities for collaboration, new avenues of research, and provision of science advice

In addition to discussing the key points of the review in the draft report, the SG cross-referenced its list of knowledge gaps and important questions with the biodiversity-related activities, past and present, that PICES has already undertaken (*SG-BC Endnote 3*, Table 2). As noted in the table, the list of knowledge gaps and questions submitted by SG-BC members were grouped into five themes, though some questions could be grouped with multiple themes. The five themes were: establishing baseline inventories of species and habitats; monitoring to understand drivers of temporal trends in biodiversity; analyses to understand and predict spatial patterns in species or habitat distributions; vulnerability assessment of species and habitats; quantitative tools to support marine spatial planning and ecosystem-based management. Cross-referencing with PICES past and present activities shows that most knowledge gaps and questions identified by SG-BC have not yet been investigated by PICES expert groups. Thus SG-BC agreed there were several opportunities for new avenues of research.

5. Advice to Science Board on merits and roles of a new biodiversity expert group

In evaluating the merits of establishing a new expert group to focus on biodiversity, SG-BC took into consideration the following criteria raised by the SG members:

- Seeking commonalities among PICES member countries in terms of key knowledge gaps and research questions;
- Maintaining a narrow focus for ensuring efficiency and feasibility;
- Avoiding duplication in effort by other PICES expert groups;
- Avoiding duplication in effort by member countries within national waters: thus, consider focus on international waters;
- Developing Terms of Reference and action plan that are achievable with available resources;
- Aiming for a medium term duration of 2–5 years (*e.g.*, 3-year working group);
- Application: relevance for supporting management decisions.

Members discussed each theme in terms of developing an expert group to engage in related biodiversity research. Several ideas were proposed. Three options for a new biodiversity expert group were identified in particular (*SG-BC Endnote 3*, Table 3):

1. Establishment of a network of ocean observation sites for characterizing and monitoring changes in the distribution, abundance and diversity patterns of indicator species (*e.g.*, microbial communities, plankton, and nekton). Patterns in distribution and diversity would be correlated with environmental variables to identify key drivers of change and potential predictors. It was noted that the Kurishio Current influences the species distributions of five member countries (China, Korea, Japan, Russia and U.S.), and potential observation sites were proposed along the current as well as in the northeast Pacific Ocean.
2. Development of guidance on methods for monitoring changes in marine biodiversity. Guidance could address questions related to selection of indicator species, standards for data collection and analysis of temporal trends, advice on the distribution and networking of monitoring sites, a standard ecological or habitat classification system. This would lay a framework for future PICES research related to assessment and monitoring of marine biodiversity in the North Pacific Ocean.
3. Mapping known and predicted distributions of structure-forming species (or biogenic habitats) throughout the North Pacific Ocean, and relating patterns in distribution and diversity to potential drivers of biodiversity change. This proposal was viewed as added value in that PICES has not previously focused on deepwater benthic habitats/ecosystems or structure forming organisms. The work would be focused, with the potential of supporting assessments of vulnerable marine ecosystems (VMEs) led by the North Pacific Fisheries Commission (NPFC) or identification of ecologically and biologically significant areas (EBSAs) led by Convention on Biological Diversity (CBD). Structure-forming species were viewed as important indicators of biodiversity and of conservation interest. Members also discussed the potential for a working group to provide technical guidance to PICES on methods for developing and applying predictive models of species distributions, habitats, and biodiversity, and identifying hotspots of biodiversity.

AGENDA ITEM 3
Proposal for a new working group

There was consensus among SG-BC members to develop a proposal to establish a new biodiversity working group to focus research on option c, the distribution and diversity of structure-forming species in the deep sea waters of the North Pacific Ocean (*SG-BC Endnote 4*), but to recommend that PICES undertake options a and/or b in the future.

In addition SG-BC chairperson invites members to submit the names and affiliations of potential experts for a working group focused on biodiversity and distribution of biogenic species/habitats. Such persons could have expertise in deep sea ecology, species distribution modelling, biogenic habitats, or other related fields.

AGENDA ITEM 4
SG-BC final report

SG-BC members discussed timelines for completing the report to Science Board. Dr. Curtis proposed to integrate key points from the meeting into the draft report and circulate the new draft to all members for revision, editing and submission to Science Board by January 2015.

SG-BC Endnote 1

SG-BC participation list

Members

Janelle Curtis (Canada, Chair)
Jae Hoon Noh (Korea)
Thomas Hourigan (USA)
Wongyu Park (Korea)
Chris Rooper (USA)

Observer

Charity Mijin Lee (Korea)

PICES

Thomas Therriault (Science Board Chair)

SG-BC Endnote 2

SG-BC meeting agenda

1. Welcome, sign-in, introductions
2. SG-BC activities and progress
3. Proposal for a new working group
4. Timeline for SG-BC final report

SG-BC Endnote 3

Table 1 Key drivers of change in biodiversity identified by SG-BC members cross-referenced with PICES past and present activities.

Driver	Commonality among PICES member countries*	PICES past activities	PICES present activities
Climate change	6/6	WG 16; WG 25; SG-FERRRS; CCCC	WG 27; WG 29; S-CCME; FUTURE; AP-COVE
Pollution	5/6	SG-MP; WG 2, WG 15	WG 31; S-HAB
Fishing	4/6	–	–
Coastal development	4/6	–	AP-AICE
Non-indigenous species	3/6	–	WG 21
Ecological factors	3/6	–	–
Multiple stressors	1/6	–	WG 28

*Commonality among PICES member countries indicates the number of countries that identified a driver or stressor within the theme during their review.

SG-FERRRS = Study Group on *Fisheries and Ecosystem Responses to Recent Regime Shifts* (2003–2004)

SG-MP = Study Group on *Marine Pollutants* (2011–2013)
WG 2 = Working Group on *Development of Common Assessment Methodology for Marine Pollution* (1992–1994)
WG 15 = Working Group on *Ecology of Harmful Algal Blooms (HABs) in the North Pacific* (1999–2003)
WG 16 = Working Group on *Climate Change, Shifts in Fish Production, and Fisheries Management* (1999–2005)
WG 21 = Working Group on *Non-indigenous Aquatic Species* (2005–2013)
WG 25 = Joint PICES/ICES Working Group on *Forecasting Climate Change Impacts on Fish and Shellfish* (2008–2011)
WG 27 = Working Group on *North Pacific Climate Variability and Change* (2011–2015)
WG 28 = Working Group on *Development of Ecosystem Indicators to Characterize Ecosystem Responses to Multiple* (2011–2015)
WG 29 = Working Group on *Regional Climate Modeling* (2011–2015)
WG 31 = Working Group on *Emerging Topics in Marine Pollution* (2014–2016)
S-HAB = Section on *Ecology of Harmful Algal Blooms in the North Pacific* (2003–
S-CCME = Joint PICES/ICES Section on *Climate Change Effects on Marine Ecosystems* (2011–
CCCC = Climate Change and Carrying Capacity Program (1995–2009)
FUTURE = Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems program (2009–
AP-COVE = FUTURE Advisory Panel on *Climate Ocean Variability and Ecosystems* (2009–2014)
AP-AICE = FUTURE Advisory Panel on *Anthropogenic Influences on Coastal Ecosystems* (2009–2014)

Table 2 Key biodiversity research themes identified by PICES member countries cross-referenced with topics addressed by PICES past and present expert groups.

Biodiversity research themes	Commonality among PICES member countries*	PICES past activities	PICES present activities
Establish baseline inventory of biodiversity (species, habitats) ▪ Survey meio- and microbenthos, ▪ Survey bathyal and abyssal depths, ▪ Survey seamounts, hydrothermal vents, coldwater seeps, abyssal plain and rocky trenches, ▪ Delineate benthic and pelagic biogeographic zones	4/5	CoML/PICES Special Publication 2	–
Understand and predict spatial distribution of biodiversity ▪ Develop predictive models for key indicator, species, biogenic habitats, and diversity, ▪ Identify environmental factors that influence biodiversity patterns, ▪ Identify ecological interactions that influence biodiversity patterns	4/5	–	–
Understand and predict temporal variation in biodiversity ▪ Develop indicators to detect change, ▪ Monitor coastal ecosystems (mudflats, coral reefs, mangrove forests), ▪ Monitor marine protected areas (MPAs), ▪ Identify ecological interactions that influence biodiversity patterns	3/5	WG 21	WG 28
Vulnerability assessment ▪ Assess status of biodiversity, ▪ Assess vulnerability to climate change, ▪ Assess susceptibility to anthropogenic activities, ▪ Assess risk of non-indigenous species	3/5	WG 21	–

Analytical methods for biodiversity conservation ▪ Apply criteria for VME/EBSA, ▪ Identify reference points for indicators, ▪ Measure value of biodiversity, ▪ Define principles for MPA networks, ▪ Evaluate MPA performance, ▪ Define appropriate scales for biodiversity conservation	3/5	–	S-HD

* Commonality among PICES member countries indicates the number of countries that identified a knowledge gap or research opportunity within the theme during their review (pending submission from one PICES member country).
WG 21 = Working Group on *Non-indigenous Aquatic Species* (2005–2013)
WG 28 = Working Group on *Development of Ecosystem Indicators to Characterize Ecosystem Responses to Multiple* (2011–2015)
S-HD = Section on *Human Dimensions of Marine Systems* (2011–

Table 3 Evaluation of three research avenues for a new expert group on biodiversity.

Evaluation criteria	**Option a: Plankton/nekton biodiversity observation network**	**Option b: Technical guidance on monitoring biodiversity**	**Option c: Diversity and distribution of biogenic habitat**
Research on drivers of biodiversity change	Yes: climate change, pollution	No	Yes: climate change
Addresses common knowledge gaps identified in review	Yes: predictors of distribution; biodiversity indicators	No	Yes: deep-sea species; benthic habitats; predictors of distribution, biodiversity indicators
Clear linkages to PICES expert groups	Yes: BIO	Yes	Yes: WG 28; BIO
New PICES research	Probably not	Yes	Yes: new focus on benthic habitat
Narrow focus	Yes	Yes	Yes
Scientific paper(s)	Yes	Technical report	Yes
Achievable	Yes	Yes	Yes
Clear applications	No	Yes	Yes

SG-BC Endnote 4

Proposal for a new Working Group on *Biodiversity of Biogenic Habitats*

Parent Committee: BIO

Summary

The Study Group on *Biodiversity Conservation* (SG-BC) recommends establishment of a Working Group on *Biodiversity and Biogenic Habitats*, with an initial focus on coral- and sponge-dominated ecosystems. The proposed Working Group will advance understanding of the distribution of coral and sponge taxa in the North Pacific Ocean and their contribution to biogenic habitats and biodiversity. This effort represents a new emphasis on habitat research for PICES, and the initial focus on biogenic habitat could provide a proof of concept on how to undertake biodiversity research related to other taxa/ecosystems. Major applications of the science products developed by the Working Group would be provision of technical guidance on the development and application of species distribution models, maps of known and predicted distributions of biogenic habitats, and the development of biodiversity indicators.

Context

In 2014, PICES convened a 1-year Study Group on *Biodiversity Conservation* (SG-BC). PICES had no formal mechanism to exchange information on issues related to biodiversity in the North Pacific despite recent requests to do so, for example, from the Convention on Biological Diversity (CBD) in 2013. Marine biodiversity is important for maintaining ecosystem structure and function, which in turn supports numerous ecosystem goods and services, including sustainable fisheries.

The terms of reference for SG-BC included an assessment of the merits of establishing an expert group focused on biodiversity science within PICES, and providing recommendations on the role of such a group. Through inter-sessional work and a meeting at PICES-2014 (October 18, 2014, Yeosu, Korea) attended by members from Canada, Korea, and the United States and with written submissions from China and Japan to guide discussions, SG-BC identified several opportunities for further collaboration on marine biodiversity. Cooperation on advancing the understanding of corals and sponges as biogenic habitat in the North Pacific was deemed particularly timely and appropriate for the work of a new PICES Working Group.

Many corals and sponges are known to form fragile biogenic habitats. These three-dimensional features provide habitat for numerous fish and invertebrate species. They are associated with greater abundance of some commercially-targeted species and appear to enhance the local biological diversity of many ecosystems. Corals and sponges are also strongly influenced by biological and physical oceanographic processes, and their distribution and biodiversity are anticipated to respond to multiple stressors including global climate change, pollution, aragonite saturation, and fishing. Conservation of these biogenic habitats has been identified as a priority in a number of countries and international fora. Analyses of the spatial distribution and diversity of these taxa and associated fauna in the North Pacific have lagged significantly behind studies in the North Atlantic.

The merits of this focus include:

- A new research avenue for PICES, with clear linkages to PICES activities, particularly BIO, WG 28;
- An initial focus on biogenic habitat serves as a model for future biodiversity research on other taxa/ecosystems and addresses a lack of knowledge of benthic habitats in deeper waters;
- New data from at least five PICES members countries (Canada, China, Japan, Korea and U.S.) could be integrated to not only better understand factors that influence distribution and trends in biogenic habitat diversity, but also to test key scientific questions of broad interest (*e.g.*, model transferability).
- The focus on gathering knowledge, assessing current status, developing indicators to monitor change, and hypotheses to forecast responses to multiple stressors is aligned with the spirit of FUTURE. Moreover, the

key outputs of this Working Group (distribution maps, biodiversity indicators) would likely be of broad interest outside of PICES.
- Addressing a targeted ecological question that can lead to scientific products within 3 years.

Terms of Reference

Year1:
- Compile data on the distribution of coral and sponge taxa, and associated fish and invertebrate assemblages in the North Pacific within National Exclusive Economic Zones (EEZs) and facilitate their submission to appropriate biodiversity databases (*e.g*., Ocean Biogeographic Information System (OBIS));
- Compile data on key variables (temperature, velocity, ocean acidification, slope, aspect) hypothesized to influence coral and sponge distribution and diversity and catalogue sources of multibeam/swathe bathymetry data for distribution modeling within National EEZs;
- Hold a WG meeting, in conjunction with the PICES Annual Meeting.

Year 2:
- Review modeling approaches to predict the potential distributions of species and habitat suitability for corals and sponges (*e.g*., MaxEnt, Boosted Regression Trees, or high resolution bathymetry-based models) within National EEZs;
- Identify environmental and ecological predictors of patterns in the distribution and biodiversity of coral, sponge and associated taxa within National EEZs;
- Convene a session on biogenic habitat distribution and diversity at PICES Annual Meeting;
- Hold a WG meeting, in conjunction with PICES Annual Meeting.

Year 3:
- Review and propose potential indicators for assessing and monitoring diversity of biogenic habitats;
- Review and document associations between commercially important fish and invertebrate species and biogenic habitats;
- Prepare scientific reports for dissemination of results;
- Hold a WG meeting, in association with the PICES Annual Meeting.

Key scientific outputs:

- Technical guidance on development and application of predictive species and habitat modeling approaches for deep-sea corals and sponges;
- Maps of known and predicted distribution and abundance of biogenic habitat (and diversity) in North Pacific Ocean;
- Biodiversity indicators for biogenic habitat assessment and monitoring.

Appendix 4

PICES Press Articles Related to SG-BC

July 2001 ISSN 1195-2512 Vol. 9 No. 2

PICES Press

Newsletter of the North Pacific Marine Science Organization (Published semi-annually)

Climate, biodiversity and ecosystems of the North Pacific

The land of Aloha welcomed over 60 participants to the workshop on the "Impact of Climate Variability on Observation and Prediction of Ecosystem and Biodiversity Changes in the North Pacific". This workshop was jointly sponsored by PICES, the International Pacific Research Center (IPRC) based in Honolulu, and the Census of Marine Life (CoML), and was held March 7-9, 2001, in Honolulu. The organizers were Vera Alexander (PICES Vice-Chairman) and Patricia Livingston (PICES Science Board Chairman). Attendees included many members of PICES Committees, Working Groups, Advisory Panels, and the PICES-GLOBEC Climate Change and Carrying Capacity Program, in addition to other members of the North Pacific marine scientific community. Representatives of many marine organizations participated, including those from CLIVAR, CoML, DBCP, GEM, GOOS, IATTC, IPHC, IPRC, and POGO.

The Census of Marine Life seeks to answer the broad question of what did live, what does live, and what will live in the oceans. This goal complements the PICES objective of advancing scientific knowledge about the ocean environment, weather and climate change, living resources and their ecosystem,s and the impacts of human activities. In order to understand past, present, and future biodiversity, we need to understand and predict climate influences on marine ecosystems.

This workshop was a first step in reviewing the goals and strategies for observing North Pacific marine ecosystems and their biodiversity in order to improve our ability to predict ecosystem change. Participants described time series that are presently available for all parts of North Pacific ecosystems, including: 1) physical/chemical oceanography and climate, 2) phytoplankton, zooplankton, micronekton and benthos, 3) fish, squid, crabs and shrimps, and 4) migratory fish, bird, and mammals. Presentations also included discussion of possible factors responsible for observed trends in the data. Predictive and explanatory models (from purely physical to coupled biophysical models) were also presented.

Announcing a new Internet home for PICES, effective immediately

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New Secretariat e-mail addresses:

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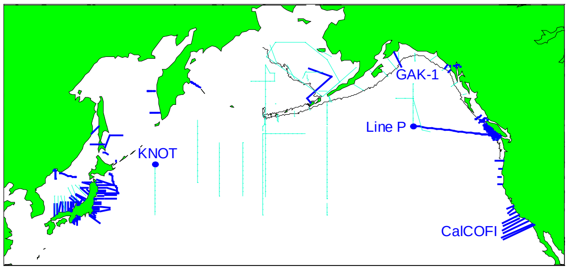

Fig. 1 All locations that are sampled at least once per year. Those sampled more frequently than once per year appear in dark blue.

Many examples of change in animal distribution, abundance, or survival in relationship to local climatic factors such as temperature or transport or to large-scale regional climate indices were shown. It was evident from maps of where data had been collected in the North Pacific Ocean that the open ocean is less well-sampled than the shelf regions for all types of physical, chemical and biological observations (Fig. 1). For lower trophic level species such as phytoplankton and zooplankton, it appears that one of the biggest gaps was taxonomic analysis and methods for standardization/intercomparison of sampling gears. Recommendations were made for candidate indicator species and sensitive measures of change for higher trophic level species such as fish, squid, mammals and birds. It was noted that reproductive success is one of the most sensitive indicators for these groups.

One of the main purposes of the workshop was to facilitate the compilation of data and knowledge of the status and trends of North Pacific ecosystem components into a North Pacific Ecosystem Status Report. This concept was brought to the attention of the PICES scientific community and Governing Council at the 9th Annual Meeting of PICES. A study group is now using the results and recommendations from this workshop to refine the concept and to determine how to compile such a report. The purpose of the North Pacific Ecosystem Status report is to integrate our collective scientific knowledge of the North Pacific and its changes and to inform the scientific community and policy- and decision-makers in the North Pacific region of ecosystem changes and the factors influencing change. Ultimately, the goal is to provide predictions of change that can be used to move towards ecosystem-based marine policy- and decision-making.

Workshop recommendations mostly dealt with the steps to be taken to produce a North Pacific Ecosystem Status Report. Many recommendations made in each of the breakout group discussions were specific to each particular group. However, some of the recommendations that were discussed in the closing plenary covered all disciplines. One main recommendation was to include all the information regarding time series data that was identified at the workshop into the North Pacific Ecosystem Meta-database, presently maintained by U.S. researchers Allen Macklin and Bernard Megrey. The meta-database contains information about the data, but does not include the data. Compiling information on existing time series data will be very useful when structuring the Ecosystem Status Report.

Participants recognized the need for PICES member nations to pool observational resources to provide a complete sampling program in the open ocean areas of the North Pacific. It was also recommended that PICES make formal connections with programs that are planning coordinated, technologically-advanced observation and communication systems, such as the NEPTUNE underwater observatory for the northeast Pacific. A variety of technological advancements in monitoring efforts from physics to upper-trophic level species were recommended as pilot projects for PICES scientists and groups to consider in the near future. These included putting instruments on ships-of-opportunity, putting biological sensors on buoys, improving sampling methodology for small pelagic fishes and video monitoring of birds and mammals on continuous plankton recorder cruises.

The concept of Regional Analysis Centers (RACs) was discussed as a way for PICES to focus the work involved in producing an Ecosystem Status Report. Two ways of viewing these centers were mentioned. One type of RAC would be an actual geographic location and building with staff assigned to it. Another type would be more of a "virtual" RAC that would rely heavily on a distributed network of scientists to contribute to the work. It seemed clear from the organization examples mentioned in discussion, that even a "virtual" RAC would still need some central support to accomplish the work.

The full report of this workshop is being compiled and is scheduled for publication before the PICES 10th Anniversary Meeting. The North Pacific Ecosystem Status Report and Regional Analysis Center Study Group, formed by PICES in 2000, will be considering the recommendations and discussions of this workshop in order to prepare: 1) a detailed outline for the first Status Report, 2) identification of key contributors and data sources and how the data would be synthesized into the report, 3) estimate costs, and 4) possible role of RACs., e for consideration by the PICES scientific community. Hopefully, work can begin on compiling the North Pacific Ecosystem Status Report after PICES X.

The report was prepared by **Pat Livingston**, Chairman of the PICES Science Board and co-convenor of the 2001 Census of Marine Life workshop in Honolulu.

KORDI/PICES/CoML Workshop on “Variability and status of the Yellow Sea and East China Sea ecosystems”

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Dr. Sinjae Yoo is the Director of Marine Living Resources Research Division in KORDI (Korea Ocean Research & Development Institute) and is based in Ansan, Korea. Sinjae received his B.S. and M.S. in Oceanography from the Seoul National University, and his Ph.D. in Ecology and Evolution from the State University of New York at Stony Brook. He has been involved in various research projects including the Yellow Sea Large Marine Ecosystem. He was a panel member of IOCCG and Coastal-GOOS. Over the years, Sinjae has been involved with PICES, serving on the Biological Oceanography Committee and the MODEL Task Team. His research interests include long-term change in primary production and phytoplankton dynamics in various marine environments.

Background

The Yellow Sea and East China Seas (YS-ECS) are epi-continental seas (Fig. 1) bounded by the Korean Peninsula, mainland China, Taiwan, and some Japanese islands (Ryukyu and Kyushu). Presumably, the YS-ECS ecosystems, with dense population living along the coasts, are amongst the ecosystems in the Pacific that are under the strongest influence of various human activities, such as fishing, mariculture, waste discharge, dumping and habitat destruction. There has also been strong evidence showing a gradual increase in the water temperature in the past decades. Given the variety of forcing factors, complicated changes in the ecosystem are anticipated. Indeed, rapid change and large fluctuations in the species composition and abundance in the major fisheries have occurred. In this respect, it was timely that the YS-ECS ecosystem status was evaluated as a part of the PICES and Census of Marine Life (CoML) efforts of status assessment of the North Pacific Ecosystems. A workshop for this purpose was scheduled in April 2003, to gather scientists who have been working in this region and to discuss and summarize what they learned about the YS-ECS ecosystems during the past. Many scientists expressed interests in participating in the workshop, however, the workshop was postponed twice due to the outbreak of SARS in the spring of 2003. The workshop was finally held October 9, 2003, immediately prior to the PICES Twelfth Annual Meeting in Seoul, and convened by Drs. Sinjae Yoo and Hyung-Tack Huh (KORDI), and Skip McKinnell and Ian Perry (PICES). A draft chapter on the status of YS-ECS ecosystems for the PICES North Pacific Ecosystem Status Report (NPESR) was written before the workshop based on the contributions by Drs. Hiroshi Ichikawa, Xian-Shi Jin, Young-Shil Kang, Suam Kim, Jai-Ho Oh, Sinjae Yoo, and Chang-Ik Zhang, instead of after the workshop as was originally planned. This way, the workshop was more focused on the discussion of the draft.

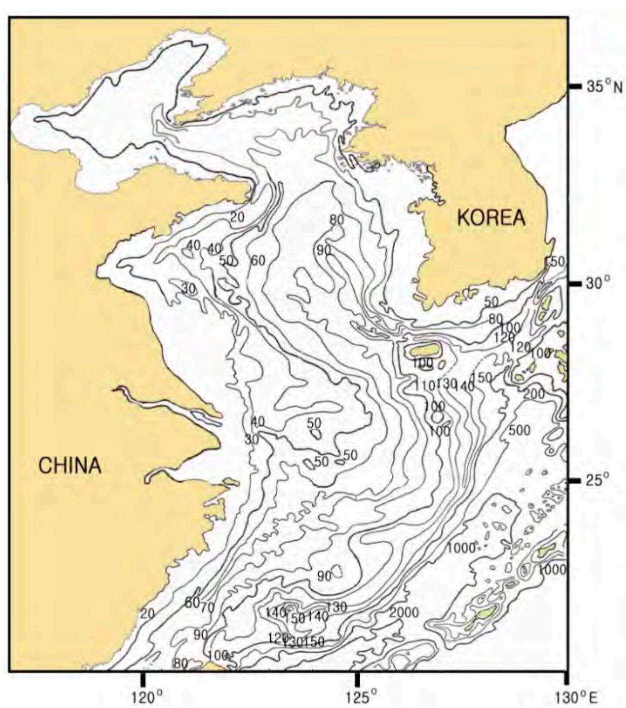

Fig. 1 Geography and bathymetry of the Yellow Sea and the East China Sea.

Overview of presentations

About twenty scientists from all PICES member countries participated in the workshop. Since the workshop was more focused on revising the draft chapter, presentations and discussion were done in a very informal fashion. Dr. Ian Perry (Chairman of PICES Science Board) gave a general introduction to the NPESR project. The objectives, structure and target audience of the report were briefly explained.

Dr. Sinjae Yoo (Republic of Korea) presented the outline of the draft for the YS-ECS chapter. First, geography, topography, circulation, flora and fauna of the region were described as background information. Next, potential critical factors causing change in the YS-ECS ecosystems were identified: environmental contamination, eutrophication, habitat destruction, overexploitation, and changes in the circulation. In addition to climate-related change in the circulation, the building of the Three-Gorges Dam in the upper reaches of the Changjiang River could bring changes to the ecosystem. Possible adverse effects were pointed out such as a decrease in the primary productivity in the vicinity and reduced flushing in the YS. Then, details were described for physics, climate and chemistry of the region. There has been an increase of 1.8ºC in the water temperature in February in the seas around Korea during the past one hundred years. The rate of change became greater during the past decade. The nutrient loads into the sea have more than doubled during the last two decades. Data of heavy metals, PCBs, PAHs, and other persistent organic pollutants were shown. Phytoplankton species composition and primary productivity of the region were discussed next. There seem to be still uncertainties in the primary production estimates for both the YS and ECS. It seems interesting that both phytoplankton and zooplankton biomass increased in the YS since the late 1980's (Fig. 2).

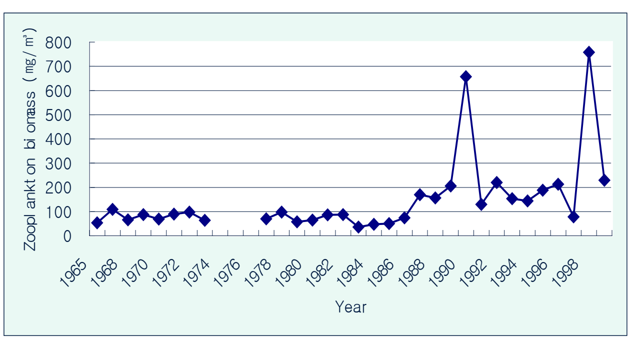

Fig. 2 Time series of average annual zooplankton biomass (mg/m^3) in the eastern Yellow Sea (from bi-monthly surveys during 1965-1999, data by Y. S. Kang).

Another sign of ecosystem change is the abrupt increase in the HAB incidences in Chinese and Korean waters causing huge economic damages. Concurrently with the changes in the physics, chemistry and lower trophic level, there have been dramatic changes in the higher trophic level in the YS and ECS as evidenced by fisheries data in the past three decades. Such changes can be summarized as follows. First, declines in biomass and catch of demersal species have occurred, and as a result, pelagic species have increased in catch proportions, while demersals have decreased. Second, the catch of pelagics species showed large fluctuations. Third, the average trophic level of fishery catches has gradually decreased, more rapidly in the YS than in the ECS (Fig. 3). Following fisheries data, a brief description was made on the endangered species in the YS.

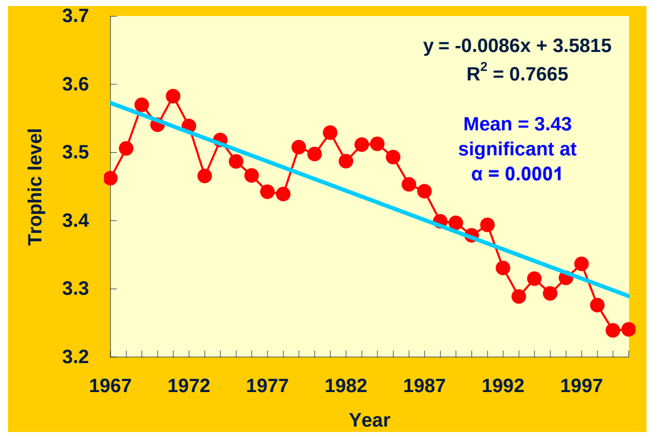

Fig. 3 Time series of average trophic level from the catch of resource organisms in the Yellow Sea (data by C.I. Zhang)

After the presentation of the draft outline, talks were given for each area ranging from climate and physics to fisheries. Dr. Jai-Ho Oh (Republic of Korea) reported on long-term changes in the air temperature in Korean cities. He showed that there has been an increase of 0.11~0.23°C/decade since the 1910's at eight cities. The number of summer days increased by 22, while the number of winter days decreased by 27 days, showing a clear trend of warming. He also presented projections of future acceleration in the temperature rise using the regional climate MM5 model.

The next two presentations were on physical oceanography of the region by Drs. Heung-Jae Lie (Republic of Korea) and Hiroshi Ichikawa (Japan). Dr. Lie discussed the origins of the Jeju Warm Current and Tsushima Warm Current, and seasonality of the coastal currents. Using drifter data, he showed that the Tsushima Current branches from Kuroshio along the shelf edge of the ECS. In the YS, strong cyclonic circulation develops along the coasts in summer, while in winter, southward currents develop along both Chinese and Korean coasts. Dr. Ichikawa summarized the general characteristics and forcing of the regional currents. His talk focused on the inter-annual variation in the Changjiang (Yangtze) River discharge and its influence on the oceanographic properties in the vicinity. Classification analysis of water masses in the ECS using T, S, nutrients and chlorophyll-*a* was also presented.

After presentations on the physics and climate in the morning session, talks on chemistry and biology followed in the afternoon. Dr. Jae-Ryoung Oh (Republic of Korea) showed results of the pollution surveys in the YS in 2000. Heavy metals, and organochlorine compounds including pesticides, PCBs and PAHs were analyzed from samples of sediments, tissues and liver of fish. Except for a few hotspots, in most of the samples the level of these pollutants was below the known safe values. However, there are no criteria for safety for some chemical species and continued monitoring is necessary.

Dr. Xian-Shi Jin (People's Republic of China) presented Chinese records of dominant species of phytoplankton, zooplankton, and major fisheries species in the YS, ECS and Bohai Sea. The trend of major fisheries species composition paralleled that which was observed in the Korean waters, *e.g.*, pelagics increased while demersal decreased. As an example of large fluctuations in the pelagics, he described the case of Japanese anchovy (*Engraulis japonicus*) which collapsed in the early 2000's. In contrast to the Korean records that showed a doubling trend in the zooplankton biomass in the YS since the late 1980's, the zooplankton biomass in the Chinese side decreased during the same period.

Dr. Ming-Yuan Zhu (People's Republic of China) presented the recent trend in HAB outbreaks in the ECS. The most frequent time of the outbreaks was from May to June. There was a dramatic increase in the reported HAB outbreaks since 2001, partly due to intensified monitoring activities. He also reported on the oceanographic conditions of the outbreaks in 2002. In 2002, 79 events were reported, 55 of which occurred in the ECS and 4 occurred in the YS. It was suggested that changes in the N/P ratio might be important in the HAB outbreaks.

Investigation, using satellite data, on whether there have been real changes in the YS ecosystem over the past two decades was the topic of the next presentation by Seung-Hyun Son (Republic of Korea). He compared data of two ocean color sensors CZCS (Coastal Zone Color Scanner: 1978~1986) and SeaWiFS (Sea-viewing Wide Field-of-view Sensor: 1997~present). On average, higher chlorophyll values were seen in SeaWiFS data. Likewise, water-leaving radiance decreased at 443 nm and increased at 555 nm (Fig. 4). The *in-situ* data showed less evidence of decadal trends, but there were slight increases in temperature and zooplankton biomass, and slight decreases in salinity and Secchi depth.

Dr. Bernard Megrey (U.S.A.) gave a brief introduction to the North Pacific Ecosystem Metadatabase promoted by NOAA. He demonstrated the metadatabase webpage and asked the audience for future participation.

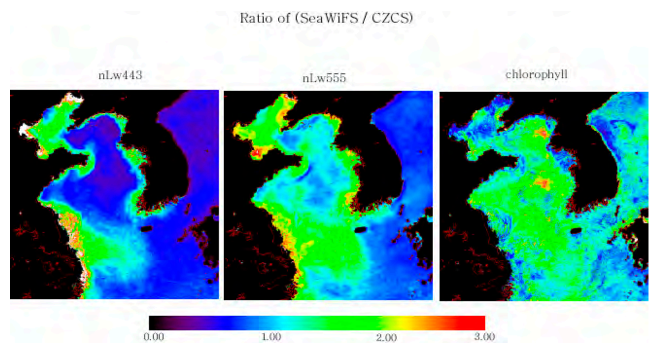

Fig. 4 Comparison of composite bio-optical values from CZCS (1979-1984) and SeaWiFS (1998-2002) (data by S.H. Son).

Discussion

The discussions that followed focused on how to improve the draft of the YS-ECS chapter. The main question was "What is missing and whether such information is available?" A number of items were listed including alien species, parasites, disease and bacterioplankton. Data might be available for these items but too scanty to be representative values. There are some items such as benthos with good data coverage, and certainly should be incorporated in the draft. Also the distribution and productivity of commercial invertebrates, and the impact of aquaculture on natural communities would be valuable information for assessing the ecosystem status. Fish catch data in China as well as in Korea in the draft need to be updated as some pelagic fishes show high frequency fluctuation.

In addition to the missing data, discrepancies were found between datasets. For example, the zooplankton biomass in Korean waters in the YS increased since the late 1980's, while that in Chinese waters decreased in the same period. Sampling details should be compared to interpret such discrepancy. This illustrates the need for comparable sampling methods and gears in the future.

There were different views about the impact of the Three-Gorges Dam on the YS-ECS ecosystems: some think the impact would be substantial, while others believe not. But most participants agreed on the need to monitor the future change. Then there was a suggestion that a PICES Working Group might be needed for this interesting semi-natural macrocosm experiment.

The YS and ECS are ecosystems where you can find complicated action of multiple forcing factors. Will we ever be able to understand what factors contribute, and how much, to the ecosystem change we observe?

The new PICES Working Group on *Ecosystem-based management*

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Dr. Glen Jamieson is a research scientist at the Pacific Biological Station (Fisheries & Oceans Canada) who has 18 years' experience in shellfish stock assessment. His research and provision of scientific advice is currently centered in four general areas: 1) research in support of the establishment of marine protected areas (MPAs) and ecosystem-based management in British Columbia; 2) development of appropriate steward-ship and monitoring protocols; 3) evaluation of the population dynamics and responses of selected species, focusing on relatively sedentary species such as benthic invertebrates, rockfish, and lingcod; and 4) investigation and monitoring of the presence and impacts of exotic species. Glen is a member of the PICES MEQ Committee and the Chairman of the Study Group on Ecosystem-based management science and its application to the North Pacific.

Since the industrial revolution, man's impact on the oceans has increased dramatically, this being especially true in recent years. In near-shore coastal areas, human population growth has led to increasing pollution and habitat modification. Fishing effects have become increasingly severe, with many, if not most, traditionally harvested populations now either fully exploited or over-fished (Garcia and Moreno, 2003). Thus far, management of these activities has been primarily sector-focused. For instance, fisheries have generally been managed in isolation of the effects of other influencing factors, and have targeted commercially important species, without explicit consideration of non-commercial species and broader ecosystem impacts. However, there is now an increasing international awareness of the cumulative impacts of sector-based activities on the ecosystem (Jennings and Kaiser, 1998; Kaiser and De Groot, 2000), and the need to take a more holistic or ecosystem-based management (EBM) approach (Anon., 1999; Kabuta and Laane, 2003; Link, 2002) to ensure the sustainability of marine ecosystems. Globally, there is an emerging paradigm shift in our approach to ocean management and usage (Sinclair and Valdimarsson, 2003).

In response to the increasing awareness to look at cumulative environmental impacts, in October 2003, the PICES Science Board established, under the direction of the Fishery Science (FIS) and Marine Environmental Quality (MEQ) Committees, the Study Group on *Ecosystem-based management science and its application to the North Pacific*, with the following terms of reference:

1) Review and describe existing and anticipated ecosystem-based management initiatives in PICES member nations and the scientific bases for them;
2) Identify emerging scientific issues related to the implementation of ecosystem-based management; and
3) Develop recommendations for a Working Group to focus on one or more of the issues identified.

The first Study Group task was to reach a common understanding of what the terms ecosystem and ecosystem-based management meant. The following definitions were agreed to:

Ecosystem: The spatial unit and its organisms and natural processes (and cycles) that is being studied or managed.

Ecosystem-based management: A strategic approach to managing human activities that seeks to ensure through collaborative stewardship the coexistence of healthy, fully functioning ecosystems and human communities [towards maintaining long-term system sustainability] by integrating ecological, economic, social, institutional and technological considerations.

Representatives from each country then submitted a summary of their country's approach to EBM, and it became immediately obvious that challenges were different between China, Japan and Korea *vs.* Russia, Canada and the United States. The greater coastal populations in the former three countries, coupled with their much longer history of full exploitation of most harvestable renewable resources, meant that EBM was, initially at least, focused on 1) minimising existing impacts, 2) rebuilding depleted stocks to more acceptable levels, and 3) in near-shore areas in particular, minimising widespread impacts in the marine environment from land runoff from both industrial and urban developments. In contrast, in the latter three countries, human coastal populations and development were generally much less, with fishing impacts and offshore oil and gas development identified as the major impacts. In many instances, relatively unimpacted, pristine habitat and biological communities still existed, and so the challenges there were often how to maintain them while permitting appropriate new economic activity to occur.

When the Study Group met at PICES XIII (Honolulu, October 2004), there was much discussion around three issues:

1) What would be an appropriate standard format to document environmental impacts and initiatives to minimise them;
2) How could the PICES region be subdivided into what the Study Group termed eco-regions; and
3) What indicators would be most appropriate to evaluate progress in achieving EBM.

While it is recognised that many human activities impact the marine environment (*e.g*., fishing, mariculture, oil and gas exploration and development, pollution from land-based activities, disruption of freshwater discharges by urbanisation, *etc*.), the most comprehensive databases (*e.g*., target species landings, bycatch and discard characteristics, habitat disruption, *etc*.) as to how these impacts are affecting marine ecosystems are related to fishing activities. Hence, much initial reporting of ecosystem impacts is likely to be focused on documenting and addressing fishery impacts. Alternate reporting formats may need to be assessed or developed that capture the ecosystem effects resulting from other human activities, and that describe how these ecosystem effects are being monitored. Ecosystem parameters already, or potentially, being monitored may capture environmental change, without linking this change back to the specific human activity, or activities, that in fact might be causing the change (*e.g*. increasing sea water temperature may be the result of many causes, some of which relate to human activities). In some cases, additional research may then be required to determine linkages. It was thus proposed by the Study Group that a standardised reporting framework that describes human activity impacts be progressively applied to all fisheries in PICES member countries, and that the adopted reporting framework be robust enough to address an increasing number of environmental and other requirements imposed by legislation, certification schemes, and consumer and community demands.

Eco-regions have been defined by Canada as "*a part of a larger marine area (eco-province) characterized by continental shelf-scale regions that reflect regional variations in salinity, marine flora and fauna, and productivity*". Biological communities between each region are somewhat different, but within a region, they are generally similar, at least on the large scale. There would obviously be differences between habitats (*e.g*., estuarine, rocky, soft substrate, *etc*.) within an eco-region, but overall, the same mix of species could be expected to occur. EBM approaches within an eco-region should thus strive to achieve the same broad conceptual objectives of trying to preserve the natural species mix, proportions across trophic levels, water quality, and so on. Since some eco-regions might transgress national boundaries, this might mean that different countries would be trying to address the same ecological objectives in their own waters within the same eco-region. The Study Group thus indicated that it would be of value to have a collective evaluation of where different eco-region boundaries are located.

It was generally agreed that while achievement of EBM was a common objective, only through monitoring could the level of progress be actually measured. For cost-effectiveness, existing monitored parameters should be first assessed as to their utility here, but it was recognised that new parameters, many associated with non-commercial species, will also have to be monitored. Different national approaches to achieving such monitoring were briefly discussed, mostly in the context of initiatives to develop a process to determine an optimal mix of parameters to monitor.

In finalising its report, the Study Group made the recommendation to its two parent Committees, FIS and MEQ, to establish a Working Group on *Ecosystem-based management*, with a 3-year duration and the following terms of reference:

- Describe and implement a standard reporting format for EBM initiatives (including more than fishery management) in each PICES country, including a listing of the ecosystem-based management objectives of each country;
- Describe relevant national marine ecosystem monitoring approaches and plans and types of models for predicting human and environmental influences on ecosystems. Identify key information gaps and research and implementation challenges;
- Evaluate the indicators from the 2004 Symposium on "Quantitative Ecosystem Indicators for Fisheries Management" for usefulness and application to the North Pacific;
- Review existing definitions of "eco-regions" and identify criteria that could be used for defining ecological boundaries relevant to PICES;
- Hold an inter-sessional workshop that addresses the status and progress of EBM science efforts in the PICES region, with the deliverable being either a special journal issue or a review article; and
- Recommend to PICES further issues and activities that address the achievement of EBM in the Pacific.

The parent Committees and Science Board accepted these recommendations, and the proposed Working Group on *Ecosystem-based management science and its application to the North Pacific* was established in October 2004. The Science Board also suggested that the full report of the Study Group be published as soon as possible in the PICES Scientific Report Series.

PICES participates in a Convention on Biological Diversity Regional Workshop

by Thomas Therriault

The United Nations, through the Convention on Biological Diversity (CBD), is in the process of identifying/describing ecologically or biologically significant marine areas (EBSAs) around the world using a series of regional workshops. Scientific criteria agreed to by the Conference of the Parties (COP) to the Convention form the basis to describe the EBSAs (see Annex 1 of COP decision IX/20) and include: productivity, biodiversity, important areas for threatened and endangered species, life history criteria required for species to survive and thrive, unique and rare features, vulnerability and fragility, and naturalness. Identification of any area as an EBSA is a scientific process recognising and describing its importance to the ecological and/or biological defining criteria – the next step in the process (yet to be taken) is to discuss and identify any special management measures that may be recommended for any particular EBSA. A regional workshop for the North Pacific was held from February 25 to March 1, 2013, in Moscow, Russia. As a recognized organization with significant knowledge of the North Pacific, PICES was asked to officially nominate an expert to participate in this workshop. It was anticipated that PICES involvement would increase the awareness of the CBD and its EBSA process within PICES, assist in the nomination of relevant experts through PICES' scientific networks, help CBD identify other relevant organizations to be invited, facilitate the use of workshop products in future marine biodiversity conservation efforts in the North Pacific to ensure sustainable use, and work with the CBD Secretariat to conduct the workshop. The author of this article was nominated and served on the steering committee for this regional workshop and as rapporteur for one of the major elements of the final workshop report that will be posted on the CBD website.

The first day of the workshop focused on several housekeeping issues. The introductions identified participants from several member countries, including Canada, Democratic People's Republic of Korea, Japan, Mexico, Philippines, Republic of Korea, and Russian Federation (see the group photo, Fig. 1). The People's Republic of China had confirmed participation but visa difficulties precluded their involvement in Moscow. In addition, a representative from the National Oceanic and Atmospheric Administration of the United States and several international organizations, including NOWPAP, NPAFC, and PICES participated in the workshop. Workshop discussions and analyses were supported by a technical team from Duke University, USA.

Following UN procedures, Dr. Alexander Shestakov (Director, WWF Global Arctic Programme) and Dr. Jake Rice (Chief Scientist, Fisheries and Oceans Canada) were identified as workshop co-chairs. In addition, rapporteurs were selected for each of the major sections of the workshop report. Each international organization was then invited to provide a presentation to workshop participants.

Fig. 1. Participants at the CBD Workshop to identify EBSAs for the North Pacific (February 25 – March 1, 2013, Moscow, Russian Federation).

Fig. 2 Dr. Therriault provides an overview of PICES to workshop participants.

Dr. Therriault described the mandate and structure of PICES, efforts of its expert groups, and products (*e.g.*, North Pacific Ecosystem Status Reports) that would be of value to this CBD process, and an overview of the PICES FUTURE program (Fig. 2). This was followed by country presentations of national processes which apply EBSA criteria or similar national processes. The first day also included a review of the criteria that would be used to identify EBSAs for the North Pacific and the scope that workshop participants would consider. All countries other than Mexico and the Russian Federation requested that their national waters not be included in this meeting for identification of EBSAs, mostly because of national processes already underway. The workshop participants agreed on the following scope for the workshop: marine areas within national jurisdiction of Mexico and the Russian Federation, marine areas beyond national jurisdictions in this region, the northern limit identified at the Western South Pacific regional workshop on EBSAs, the northeastern tropical Pacific area, and the Bering Strait, including the Russian coastal area and "Donut Hole" in the Bering Sea, but excluding the marine areas within the national jurisdiction of the USA.

Following a preliminary scoping exercise on the start of Day 2, workshop participants spent the next three days identifying EBSAs in the North Pacific using the CBD criteria, including compiling the necessary supporting documentation. By the end of the workshop, participants had agreed upon 20 EBSA units (Table 1) that will be tabled for discussion at the next meeting of COP (winter 2013 or early 2014). The report from the meeting is expected to be available soon on CBD's website.

Table 1 EBSAs identified at the CBD workshop for the North Pacific.

Number	Areas meeting EBSA criteria
1	Peter the Great Bay, Russia
2	West Kamchatka shelf, Russia
3	South East Kamchatka coastal waters, Russia
4	Eastern shelf of Sakhalin island, Russia
5	Moneron Island shelf, Russia
6	Shantary Islands shelf, Amur and Tugur Bays, Russia
7	Commander Islands shelf and slope, Russia
8	East and South Chukotka coast, Russia
9	Yamskie Islands and western Shelikhov Bay, Russia
10	Alijos Islands, Mexico
11	Coronado Islands, Mexico
12	Guadalupe Island, Mexico
13	Upper Gulf of California region, Mexico
14	Midriff Islands region, Mexico
15	Coastal lagoons and islands off Baja California and Offshore Waters Complex, Mexico
16	Juan de Fuca Ridge Hydrothermal Vents
17	Northeast Pacific Ocean Seamounts
18	Emperor Seamount Chain and Northern Hawaiian Ridge
19	North Pacific Transition Zone and bordering currents
20	Albatross Arc

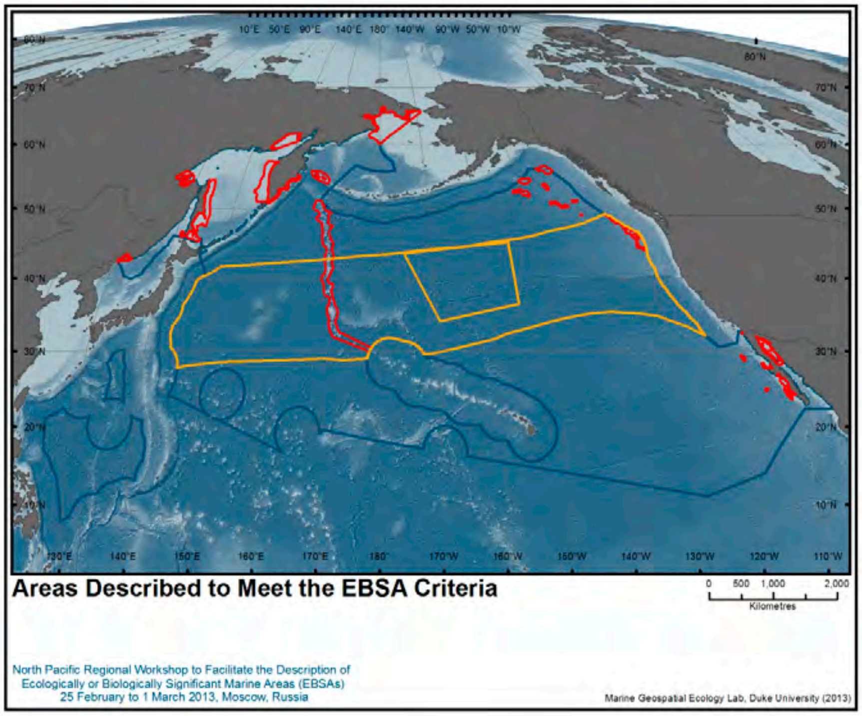

Fig. 3 Spatial extent of EBSAs developed at the CBD workshop for the North Pacific. Blue line indicates the boundary of the area considered by the workshop. Polygons in red indicate those areas described against EBSA criteria by the workshop. Polygons in orange indicate those features that are inherently not spatially fixed, and described against EBSA criteria by the workshop.

There was debate at the workshop about whether the eastern and western North Pacific gyres should be included as potential EBSAs, considering their importance for salmon populations. However, not enough information was available at the meeting to support including these regions as EBSAs at this time but participants recommended these regions should receive further consideration in future CBD processes. It is worth highlighting the area of the North Pacific Transition Zone (EBSA Number 19 identified by the large orange polygon in Fig. 3) is extraordinarily large for an EBSA, and was defined primarily on the basis of the northerly and southerly seasonal migrations of the Transition Zone chlorophyll frontal zone. The narrative describing this region notes that this is not a geographically fixed feature but one which is seasonally variable in its location. This is in contrast to the bathymetrically-fixed EBSAs proposed about the various seamount chains in the North Pacific.

PICES has considerable experience with identifying and describing ecologically and biologically important areas in the North Pacific, although it has not (yet) used the CBD EBSA terminology and criteria. Some examples include the two North Pacific Ecosystem Status Reports, topic sessions at PICES Annual Meetings (most recently in Portland in 2010), and WG 19's efforts on ecosystem-based management. The ever increasing international interest in EBSAs and current and planned global efforts to identify such areas both within and beyond country Exclusive Economic Zones (EEZs) represent an important opportunity for PICES. As an intergovernmental organization we have a wealth of science experts to consider these issues and to provide scientifically defensible recommendations not only for EBSAs but for other international initiatives currently underway in the North Pacific (*e.g.*, World Ocean Assessment; see page 12 in this issue).

Dr. Thomas Therriault (Thomas.Therriault@dfo-mpo.gc.ca) is a Research Scientist with Fisheries and Oceans Canada (DFO) at the Pacific Biological Station in Nanaimo, BC and currently is PICES Science Board Chairman-elect. Tom works on a variety of conservation biology issues including aquatic invasive species where he has an extensive research program both within DFO and through the second Canadian Aquatic Invasive Species Network (CAISN II) which includes collaborations with academia. Within PICES, Tom is the FUTURE Advisory Panel Chairman for AICE (Anthropogenic Influences on Coastal Ecosystems), a member of MEQ, a member of WG-21 on Non-indigenous marine species and most recently a member of the new NPAFC/PICES Study Group on Developing a Framework for Scientific Cooperation.

Workshop on Marine Biodiversity Conservation and Marine Protected Areas in the Northwest Pacific

by Vladimir Kulik

Fig. 1 The participants of the NOWPAP/NEASPEC workshop on "Marine biodiversity conservation and marine protected areas in the Northwest Pacific", March 13–14, 2013, in Toyama, Japan. The photo was provided by the Special Monitoring and Coastal Environmental Assessment Regional Activity Centre (CEARAC) of NOWPAP.

The beautiful city of Toyama, Japan, 300 km northeast of Tokyo, was the setting on March 13–14, 2013, for a workshop on "*Marine biodiversity conservation and marine protected areas in the Northwest Pacific*". The workshop was convened by NOWPAP (Action Plan for the Protection, Management and Development of the Marine and Coastal Environment of the Northwest Pacific Region; part of the Regional Seas Program of the United Nations Environment Program; http://www.nowpap.org/) and NEASPEC (North-east Asian Sub-program for Environmental Cooperation; http://www.neaspec.org/). The objectives of the workshop were: (1) to share information on methodologies for marine environment assessment and the current status of Marine Protected Areas (MPAs) in member states of NOWPAP, and (2) to discuss the programs and operations of the proposed North-east Asian MPA network. PICES was invited to participate in this workshop, and was represented by Dr. Vladimir Kulik, a member of the PICES Working Group 28 on *Development of Ecosystem Indicators to Characterize Ecosystem Responses to Multiple Stressors*. In addition to PICES, other participants at the workshop included experts from all NOWPAP member states (Japan, People's Republic of China, Republic of Korea and the Russian Federation) and from international organizations such as the Helsinki Commission (HELCOM; http://www.helcom.fi/) and the IOC Sub-Commission for the Western Pacific (IOC/WESTPAC; http://www.unescobkk.org/westpac). In total, more than 20 people attended the workshop (Fig. 1).

The motivation for the workshop was responsibilities to contribute to marine biodiversity conservation and sustainable use of marine ecosystem services in the NOWPAP region. The meeting had presentations and shared information on details of MPAs in the region, including definition, categories and monitoring/management status in each member state of NOWPAP. An information sheet was developed and will be finalized based on additional information provided after the workshop. The meeting discussed the similarities and differences in the definitions of MPAs among the member states and recognized the usefulness of such information for future considerations to improve the management of MPAs. Information was also shared on the challenges of maintaining and managing MPAs, as well as future plans to design and expand these areas, including the possible application of the Ecologically or Biologically Significant Sea Area (EBSA) concept developed by the United Nations (UN) Convention on Biological Diversity (CBD; http://www.cbd.int) and other organizations.

The meeting learned about ongoing related activities for assessing the marine environment being conducted by PICES, HELCOM and IOC/WESTPAC, which were recognized as being useful for the conservation of marine biodiversity in the NOWPAP region. The necessity of Ecological Quality Objectives for the NOWPAP region was stressed as a basis for setting targets for assessment and appropriate management. Collaborations among the NOWPAP member states and other regional organizations such as PICES towards the conservation of marine biodiversity were acknowledged as being crucial. Of special interest to PICES was a presentation by Dr. Maria Laamanenof (HELCOM) on "*Comprehensive ecosystem assessment for marine biodiversity conservation*". She noted that they have reached the 10 % target set by the UN CBD for a regional network of MPAs in the Baltic Sea. However, the present network may not be entirely ecologically coherent if adequacy, representativity, replication and connectivity are the primary criteria used for its assessment. The most important problems they have encountered in evaluating the effectiveness of this network of MPAs are nonlinearities and thresholds in the ecosystem recovery process. Therefore, reaching some of the targets did not lead to convergence with other targets from the same domain. As a result, widely used simplifications in the models of ecosystem assessment such as linearity and additivity must be reconsidered. HELCOM member states are in the process of summarizing their achievements in assessing the progress towards reaching HELCOM objectives for a healthy Baltic Sea, which are available at http://www.helcom.fi/BSAP_assessment/en_GB/main.

At its conclusion, the NOWPAP/NEASPEC workshop recommended the following:

- The regional monitoring centre for NOWPAP to assess the availability of data and to consider the collection of metadata and the development of assessment tools based on the available data for marine biodiversity conservation in the NOWPAP region;
- Recognizing that the indicators employed by HELCOM and those being studied by PICES are useful references for the NOWPAP region, to consider the availability of data and different conditions in the marine environment in the NOWPAP region when selecting indicators;
- Strengthen collaboration with relevant partners, for example, PICES, HELCOM and IOC/WESTPAC, when conducting the above tasks.

Fig. 2 PICES WG 28 presentation at the NOWPAP/NEASPEC workshop.

The full meeting report, with details from each NOWPAP member state, and all presentations (including that given by the author of this article (Fig. 2) on behalf of PICES WG 28) are available on the workshop website at http://www.cearac-project.org/NOWPAP_NEASPEC_Workshop/NOWPAP_NEASPEC_Joint_Workshop.htm.

Dr. Vladimir Kulik (vladimir.kulik@tinro-center.ru) is the Leading Research Scientist at the Regional Data Center of the Pacific Research Institute of Fisheries and Oceanography (TINRO-Centre) in Vladivostok, Russia. His research focuses on the fluctuation of abundance of species which are caught by pelagic and bottom trawls with 1 cm mesh during scientific surveys in the Russian part of the Northwestern Pacific Ocean since 1979. Within PICES, Vladimir is a member of the Technical Committee on Monitoring, the Working Group on Development of Ecosystem Indicators to Characterize Ecosystem Responses to Multiple Stressors (WG 28), and the FUTURE Advisory Panel on Anthropogenic Influences on Coastal Ecosystems.

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Front cover figure

Living rock – Marine biodiversity in the waters off northern Vancouver Island, Canada. Photo credit: Eiko Jones Photography.